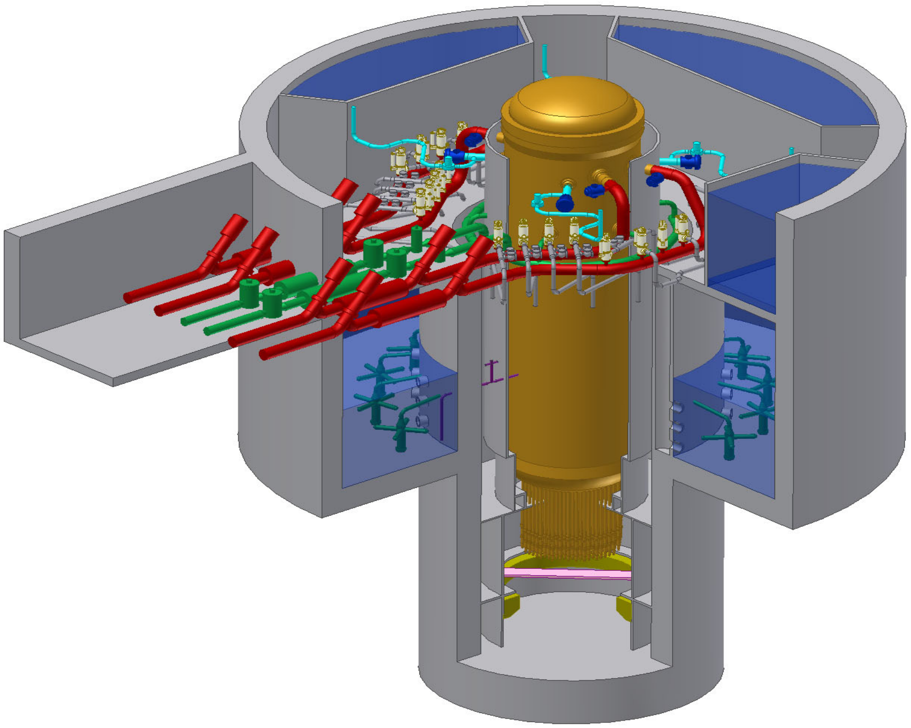
GE Nuclear Energy

26A6642BH
Revision 0
August 2005



ESBWR Design Control Document

Tier 2

Chapter 11

Radioactive Waste Management

(Conditional Release – pending closure of design verification)

Contents

11. Radioactive Waste Management	11.1-1
11.1 SOURCE TERMS	11.1-1
11.1.1 Fission Products	11.1-1
11.1.2 Activation Products	11.1-3
11.1.3 Radionuclide Concentration Adjustment	11.1-4
11.1.4 Fuel Fission Production Inventory	11.1-5
11.1.5 Process Leakage Sources	11.1-5
11.1.6 References	11.1-6
11.2 LIQUID WASTE MANAGEMENT SYSTEM	11.2-1
11.2.1 Design Bases	11.2-1
11.2.2 System Description	11.2-2
11.2.2.1 Summary Description	11.2-2
11.2.2.2 System Operation	11.2-2
11.2.2.3 Detailed System Component Description	11.2-4
11.2.3 Safety Evaluation — Radioactive Releases	11.2-6
11.2.4 Testing and Inspection Requirements	11.2-7
11.2.5 Instrumentation Requirements	11.2-7
11.2.6 COL Information	11.2-7
11.2.7 References	11.2-7
11.3 GASEOUS WASTE MANAGEMENT SYSTEM	11.3-1
11.3.1 Design Bases	11.3-1
11.3.2 Offgas System Description	11.3-2
11.3.2.1 Process Design	11.3-4
11.3.2.2 Component Design	11.3-8
11.3.2.3 Seismic Design	11.3-11
11.3.3 Ventilation System	11.3-11
11.3.4 Radioactive Releases	11.3-11
11.3.5 Testing and Inspection Requirements	11.3-11
11.3.6 Instrumentation Requirements	11.3-11
11.3.7 Radioactive OffGas System Leak or Failure	11.3-12
11.3.7.1 Basis and Assumptions	11.3-12
11.3.7.2 Results	11.3-13
11.3.8 COL Information	11.3-13
11.3.8.1 Offgas System Data	11.3-13
11.3.9 References	11.3-13
11.4 SOLID WASTE MANAGEMENT SYSTEM	11.4-1
11.4.1 Design Bases	11.4-1
11.4.2 System Description	11.4-2
11.4.2.1 Summary Description	11.4-2
11.4.2.2 System Operation	11.4-2
11.4.2.3 Detailed System Component Description	11.4-4
11.4.3 Safety Evaluation	11.4-5
11.4.4 Testing and Inspection Requirements	11.4-5

11.4.5 Instrumentation Requirements 11.4-5
11.4.6 COL Information 11.4-5
11.4.7 References 11.4-5
11.5 PROCESS RADIATION MONITORING SYSTEM 11.5-1
11.5.1 Design Bases 11.5-1
11.5.1.1 Design Objectives 11.5-1
11.5.2 System Design Bases and Criteria 11.5-2
11.5.2.1 Radiation Monitors Required for Safety 11.5-3
11.5.2.2 Radiation Monitors Required for Plant Operation 11.5-3
11.5.3 Subsystem Description 11.5-4
11.5.3.1 Radiation Monitors Required for Safety 11.5-4
11.5.3.2 Radiation Monitors Required for Plant Operation 11.5-6
11.5.4 Regulatory Evaluation 11.5-10
11.5.4.1 Basis for Monitor Location Selection 11.5-11
11.5.4.2 Expected Radiation Levels 11.5-11
11.5.4.3 Instrumentation 11.5-11
11.5.4.4 Setpoints 11.5-11
11.5.5 Process Monitoring and Sampling 11.5-11
11.5.5.1 Implementation of General Design Criterion 19 11.5-11
11.5.5.2 Implementation of General Design Criterion 60 11.5-11
11.5.5.3 Implementation of General Design Criterion 63 11.5-12
11.5.5.4 Implementation of General Design Criterion 64 11.5-12
11.5.5.5 Basis for Monitor Location Selection 11.5-12
11.5.5.6 Expected Radiation Levels 11.5-12
11.5.5.7 Instrumentation 11.5-12
11.5.5.8 Setpoints 11.5-13
11.5.6 Calibration and Maintenance 11.5-13
11.5.6.1 Inspection and Tests 11.5-13
11.5.6.2 Calibration 11.5-14
11.5.6.3 Maintenance 11.5-14
11.5.7 COL Information 11.5-14
11.5.8 References 11.5-14

List of Tables

Table 11.1-1 Source Term Design Basis Parameters
Table 11.1-2 Design Basis Noble Radiogas Source Terms in Steam
Table 11.1-3 Calculational Parameters For Source Term Adjustment
Table 11.1-4 Design Basis Iodine Radioisotopes in Reactor Water and Steam
Table 11.1-5 Design Basis Non-volatile Fission Products In Reactor Water
Table 11.1-6 Design Basis N^{16} Concentrations in Reactor Water and Steam
Table 11.1-7 Design Basis Non-coolant Activation Products in Reactor Water
Table 11.2-1 Equipment Codes (from Table 1, RG 1.143)
Table 11.2-2a LWMS Component Capacity (Tanks)
Table 11.2-2b LWMS Component Capacity (Pumps)*
Table 11.2-2c LWMS Component Capacity (Mobile Systems)
Table 11.2-3 Decontamination Factors
Table 11.2-4 Probable Inputs to LWMS from Operational Occurrences
Table 11.3-1 Offgas System Design Parameters
Table 11.3-2 Offgas System Major Equipment Items
Table 11.3-3 Equipment Malfunction Analysis
Table 11.3-4 Construction of Process Systems
Table 11.3-5 Offgas System Failure Accident Parameters
Table 11.3-6 Isotopic Source and Releases to the Environment
Table 11.3-7 Offgas System Failure Meteorology and Dose Results
Table 11.4-1 SWMS Component Capacities
Table 11.4-2 Annual Shipped Waste Volumes
Table 11.5-1 Process and Effluent Radiation Monitoring Systems
Table 11.5-2 Process Radiation Monitoring System (Gaseous and Airborne Monitors)
Table 11.5-3 Key to Radiation Monitors Shown on Figure 11.5-1
Table 11.5-4 Process Radiation Monitoring System (Liquid Monitors)
Table 11.5-5 Radiological Analysis Summary of Liquid Process Samples
Table 11.5-6 Radiological Analysis Summary of Gaseous Process Samples
Table 11.5-7 Radiological Analysis Summary of Liquid Effluent Samples
Table 11.5-8 Radiological Analysis Summary of Gaseous Effluent Samples

List of Illustrations

Figure 11.2-1. Liquid Waste Management System Process Diagram
Figure 11.3-1. Offgas System Sh 1 of 2
Figure 11.3-1. Offgas System Sh 2 of 2
Figure 11.4-1. Solid Waste Management System Process Diagram
Figure 11.5-1. Location of Radiation Monitors

Abbreviations And Acronyms

Term	Definition
10 CFR	Title 10, Code of Federal Regulations
A/D	Analog-to-Digital
AASHTO	American Association of Highway and Transportation Officials
AB	Auxiliary Boiler
ABS	Auxiliary Boiler System
ABWR	Advanced Boiling Water Reactor
ac / AC	Alternating Current
AC	Air Conditioning
ACF	Automatic Control Function
ACI	American Concrete Institute
ACS	Atmospheric Control System
AD	Administration Building
ADS	Automatic Depressurization System
AEC	Atomic Energy Commission
AFIP	Automated Fixed In-Core Probe
AGMA	American Gear Manufacturer's Association
AHS	Auxiliary Heat Sink
AHU	Air Heating Unit
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AL	Analytical Limit
ALARA	As Low As Reasonably Achievable
ALWR	Advanced Light Water Reactor
ANS	American Nuclear Society
ANSI	American National Standards Institute
AOO	Anticipated Operational Occurrence
AOV	Air Operated Valve
API	American Petroleum Institute
APLHGR	Average Planar Linear Head Generation Rate
APRM	Average Power Range Monitor
APR	Automatic Power Regulator
APRS	Automatic Power Regulator System
ARI	Alternate Rod Insertion
ARMS	Area Radiation Monitoring System
ASA	American Standards Association
ASD	Adjustable Speed Drive
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
AST	Alternate Source Term

Term	Definition
ASTM	American Society of Testing Methods
AT	Unit Auxiliary Transformer
ATLM	Automated Thermal Limit Monitor
ATWS	Anticipated Transients Without Scram
AV	Allowable Value
AWS	American Welding Society
AWWA	American Water Works Association
B&PV	Boiler and Pressure Vessel
BAF	Bottom of Active Fuel
BHP	Brake Horse Power
BOP	Balance of Plant
BPU	Bypass Unit
BPWS	Banked Position Withdrawal Sequence
BRE	Battery Room Exhaust
BRL	Background Radiation Level
BTP	NRC Branch Technical Position
BTU	British Thermal Unit
BWR	Boiling Water Reactor
BWROG	Boiling Water Reactor Owners Group
CAV	Cumulative absolute velocity
C&FS	Condensate and Feedwater System
C&I	Control and Instrumentation
C/C	Cooling and Cleanup
CB	Control Building
CBGAHVS	Control Building General Area
CBHVAC	Control Building HVAC
CBHVS	Control Building Heating, Ventilation and Air Conditioning System
CCI	Core-Concrete Interaction
CDF	Core Damage Frequency
CFR	Code of Federal Regulations
CIRC	Circulating Water System
CIS	Containment Inerting System
CIV	Combined Intermediate Valve
CLAVS	Clean Area Ventilation Subsystem of Reactor Building HVAC
CM	Cold Machine Shop
CMS	Containment Monitoring System
CMU	Control Room Multiplexing Unit
COL	Combined Operating License
COLR	Core Operating Limits Report
CONAVS	Controlled Area Ventilation Subsystem of Reactor Building HVAC

Term	Definition
CPR	Critical Power Ratio
CPS	Condensate Purification System
CPU	Central Processing Unit
CR	Control Rod
CRD	Control Rod Drive
CRDA	Control Rod Drop Accident
CRDH	Control Rod Drive Housing
CRDHS	Control Rod Drive Hydraulic System
CRGT	Control Rod Guide Tube
CRHA	Control Room Habitability Area
CRHAHVS	Control Room Habitability Area HVAC Sub-system
CRT	Cathode Ray Tube
CS&TS	Condensate Storage and Transfer System
CSDM	Cold Shutdown Margin
CS / CST	Condensate Storage Tank
CT	Main Cooling Tower
CTVCF	Constant Voltage Constant Frequency
CUF	Cumulative usage factor
CWS	Chilled Water System
D-RAP	Design Reliability Assurance Program
DAC	Design Acceptance Criteria
DAW	Dry Active Waste
DBA	Design Basis Accident
dc / DC	Direct Current
DCD	Design Control Document
DCS	Drywell Cooling System
DCIS	Distributed Control and Information System
DEPSS	Drywell Equipment and Pipe Support Structure
DF	Decontamination Factor
D/F	Diaphragm Floor
DG	Diesel-Generator
DHR	Decay Heat Removal
DM&C	Digital Measurement and Control
DOF	Degree of freedom
DOI	Dedicated Operators Interface
DOT	Department of Transportation
dPT	Differential Pressure Transmitter
DPS	Diverse Protection System
DPV	Depressurization Valve
DR&T	Design Review and Testing

Term	**Definition**
DS	Independent Spent Fuel Storage Installation
DTM	Digital Trip Module
DW	Drywell
EB	Electrical Building
EBAS	Emergency Breathing Air System
EBHV	Electrical Building HVAC
ECCS	Emergency Core Cooling System
E-DCIS	Essential DCIS (Distributed Control and Information System)
EDO	Environmental Qualification Document
EFDS	Equipment and Floor Drainage System
EFPY	Effective full power years
EFU	Emergency Filter Unit
EHC	Electrohydraulic Control (Pressure Regulator)
ENS	Emergency Notification System
EOC	Emergency Operations Center
EOC	End of Cycle
EOF	Emergency Operations Facility
EOP	Emergency Operating Procedures
EPDS	Electric Power Distribution System
EPG	Emergency Procedure Guidelines
EPRI	Electric Power Research Institute
EQ	Environmental Qualification
ERICP	Emergency Rod Insertion Control Panel
ERIP	Emergency Rod Insertion Panel
ESF	Engineered Safety Feature
ETS	Emergency Trip System
FAC	Flow-Accelerated Corrosion
FAPCS	Fuel and Auxiliary Pools Cooling System
FATT	Fracture Appearance Transition Temperature
FB	Fuel Building
FBHV	Fuel Building HVAC
FCI	Fuel-Coolant Interaction
FCM	File Control Module
FCS	Flammability Control System
FCU	Fan Cooling Unit
FDDI	Fiber Distributed Data Interface
FFT	Fast Fourier Transform
FFWTR	Final Feedwater Temperature Reduction
FHA	Fire Hazards Analysis
FIV	Flow-Induced Vibration

Term	Definition
FMCRD	Fine Motion Control Rod Drive
FMEA	Failure Modes and Effects Analysis
FPS	Fire Protection System
FO	Diesel Fuel Oil Storage Tank
FOAKE	First-of-a-Kind Engineering
FPE	Fire Pump Enclosure
FTDC	Fault-Tolerant Digital Controller
FTS	Fuel Transfer System
FW	Feedwater
FWCS	Feedwater Control System
FWS	Fire Water Storage Tank
GCS	Generator Cooling System
GDC	General Design Criteria
GDCS	Gravity-Driven Cooling System
GE	General Electric Company
GE-NE	GE Nuclear Energy
GEN	Main Generator System
GETAB	General Electric Thermal Analysis Basis
GL	Generic Letter
GM	Geiger-Mueller Counter
GM-B	Beta-Sensitive GM Detector
GSIC	Gamma-Sensitive Ion Chamber
GSOS	Generator Sealing Oil System
GWSR	Ganged Withdrawal Sequence Restriction
HAZ	Heat-Affected Zone
HCU	Hydraulic Control Unit
HCW	High Conductivity Waste
HDVS	Heater Drain and Vent System
HEI	Heat Exchange Institute
HELB	High Energy Line Break
HEP	Human error probability
HEPA	High Efficiency Particulate Air/Absolute
HFE	Human Factors Engineering
HFF	Hollow Fiber Filter
HGCS	Hydrogen Gas Cooling System
HIC	High Integrity Container
HID	High Intensity Discharge
HIS	Hydraulic Institute Standards
HM	Hot Machine Shop & Storage
HP	High Pressure

Term	Definition
HPNSS	High Pressure Nitrogen Supply System
HPT	High-pressure turbine
HRA	Human Reliability Assessment
HSI	Human-System Interface
HSSS	Hardware/Software System Specification
HVAC	Heating, Ventilation and Air Conditioning
HVS	High Velocity Separator
HWC	Hydrogen Water Chemistry
HWCS	Hydrogen Water Chemistry System
HWS	Hot Water System
HX	Heat Exchanger
I&C	Instrumentation and Control
I/O	Input/Output
IAS	Instrument Air System
IASCC	Irradiation Assisted Stress Corrosion Cracking
IBC	International Building Code
IC	Ion Chamber
IC	Isolation Condenser
ICD	Interface Control Diagram
ICS	Isolation Condenser System
IE	Inspection and Enforcement
IEB	Inspection and Enforcement Bulletin
IED	Instrument and Electrical Diagram
IEEE	Institute of Electrical and Electronic Engineers
IFTS	Inclined Fuel Transfer System
IGSCC	Intergranular Stress Corrosion Cracking
IIS	Iron Injection System
ILRT	Integrated Leak Rate Test
IOP	Integrated Operating Procedure
IMC	Induction Motor Controller
IMCC	Induction Motor Controller Cabinet
IRM	Intermediate Range Monitor
ISA	Instrument Society of America
ISI	In-Service Inspection
ISLT	In-Service Leak Test
ISM	Independent Support Motion
ISMA	Independent Support Motion Response Spectrum Analysis
ISO	International Standards Organization
ITA	Inspections, Tests or Analyses
ITAAC	Inspections, Tests, Analyses and Acceptance Criteria

Term	Definition
ITA	Initial Test Program
LAPP	Loss of Alternate Preferred Power
LCO	Limiting Conditions for Operation
LCW	Low Conductivity Waste
LD	Logic Diagram
LDA	Lay down Area
LD&IS	Leak Detection and Isolation System
LERF	Large early release frequency
LFCV	Low Flow Control Valve
LHGR	Linear Heat Generation Rate
LLRT	Local Leak Rate Test
LMU	Local Multiplexer Unit
LO	Dirty/Clean Lube Oil Storage Tank
LOCA	Loss-of-Coolant-Accident
LOFW	Loss-of-feedwater
LOOP	Loss of Offsite Power
LOPP	Loss of Preferred Power
LP	Low Pressure
LPCI	Low Pressure Coolant Injection
LPCRD	Locking Piston Control Rod Drive
LPMS	Loose Parts Monitoring System
LPRM	Local Power Range Monitor
LPSP	Low Power Setpoint
LWMS	Liquid Waste Management System
MAAP	Modular Accident Analysis Program
MAPLHGR	Maximum Average Planar Linear Head Generation Rate
MAPRAT	Maximum Average Planar Ratio
MBB	Motor Built-In Brake
MCC	Motor Control Center
MCES	Main Condenser Evacuation System
MCPR	Minimum Critical Power Ratio
MCR	Main Control Room
MCRP	Main Control Room Panel
MELB	Moderate Energy Line Break
MLHGR	Maximum Linear Heat Generation Rate
MMI	Man-Machine Interface
MMIS	Man-Machine Interface Systems
MOV	Motor-Operated Valve
MPC	Maximum Permissible Concentration
MPL	Master Parts List

Term	Definition
MS	Main Steam
MSIV	Main Steam Isolation Valve
MSL	Main Steamline
MSLB	Main Steamline Break
MSLBA	Main Steamline Break Accident
MSR	Moisture Separator Reheater
MSV	Mean Square Voltage
MT	Main Transformer
MTTR	Mean Time To Repair
MWS	Makeup Water System
NBR	Nuclear Boiler Rated
NBS	Nuclear Boiler System
NCIG	Nuclear Construction Issues Group
NDE	Nondestructive Examination
NE-DCIS	Non-Essential Distributed Control and Information System
NDRC	National Defense Research Committee
NDT	Nil Ductility Temperature
NFPA	National Fire Protection Association
NIST	National Institute of Standard Technology
NICWS	Nuclear Island Chilled Water Subsystem
NMS	Neutron Monitoring System
NOV	Nitrogen Operated Valve
NPHS	Normal Power Heat Sink
NPSH	Net Positive Suction Head
NRC	Nuclear Regulatory Commission
NRHX	Non-Regenerative Heat Exchanger
NS	Non-seismic (non-seismic Category I)
NSSS	Nuclear Steam Supply System
NT	Nitrogen Storage Tank
NTSP	Nominal Trip Setpoint
O&M	Operation and Maintenance
O-RAP	Operational Reliability Assurance Program
OBCV	Overboard Control Valve
OBE	Operating Basis Earthquake
OGS	Offgas System
OHLHS	Overhead Heavy Load Handling System
OIS	Oxygen Injection System
OLMCPR	Operating Limit Minimum Critical Power Ratio
OLU	Output Logic Unit
OOS	Out-of-service

Term	Definition
ORNL	Oak Ridge National Laboratory
OSC	Operational Support Center
OSHA	Occupational Safety and Health Administration
OSI	Open Systems Interconnect
P&ID	Piping and Instrumentation Diagram
PA/PL	Page/Party-Line
PABX	Private Automatic Branch (Telephone) Exchange
PAM	Post Accident Monitoring
PAR	Passive Autocatalytic Recombiner
PAS	Plant Automation System
PASS	Post Accident Sampling Subsystem of Containment Monitoring System
PCC	Passive Containment Cooling
PCCS	Passive Containment Cooling System
PCT	Peak cladding temperature
PCV	Primary Containment Vessel
PFD	Process Flow Diagram
PGA	Peak Ground Acceleration
PGCS	Power Generation and Control Subsystem of Plant Automation System
PH	Pump House
PL	Parking Lot
PM	Preventive Maintenance
PMCS	Performance Monitoring and Control Subsystem of NE-DCIS
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PQCL	Product Quality Check List
PRA	Probabilistic Risk Assessment
PRMS	Process Radiation Monitoring System
PRNM	Power Range Neutron Monitoring
PS	Plant Stack
PSD	Power Spectra Density
PSS	Process Sampling System
PSWS	Plant Service Water System
PT	Pressure Transmitter
PWR	Pressurized Water Reactor
QA	Quality Assurance
RACS	Rod Action Control Subsystem
RAM	Reliability, Availability and Maintainability
RAPI	Rod Action and Position Information
RAT	Reserve Auxiliary Transformer
RB	Reactor Building

Term	Definition
RBC	Rod Brake Controller
RBCC	Rod Brake Controller Cabinet
RBCWS	Reactor Building Chilled Water Subsystem
RBHV	Reactor Building HVAC
RBS	Rod Block Setpoint
RBV	Reactor Building Vibration
RC&IS	Rod Control and Information System
RCC	Remote Communication Cabinet
RCCV	Reinforced Concrete Containment Vessel
RCCWS	Reactor Component Cooling Water System
RCPB	Reactor Coolant Pressure Boundary
RCS	Reactor Coolant System
RDA	Rod Drop Accident
RDC	Resolver-to-Digital Converter
REPAVS	Refueling and Pool Area Ventilation Subsystem of Fuel Building HVAC
RFP	Reactor Feed Pump
RG	Regulatory Guide
RHR	Residual heat removal (function)
RHX	Regenerative Heat Exchanger
RMS	Root Mean Square
RMS	Radiation Monitoring Subsystem
RMU	Remote Multiplexer Unit
RO	Reverse Osmosis
ROM	Read-only Memory
RPS	Reactor Protection System
RPV	Reactor Pressure Vessel
RRPS	Reference Rod Pull Sequence
RSM	Rod Server Module
RSPC	Rod Server Processing Channel
RSS	Remote Shutdown System
RSSM	Reed Switch Sensor Module
RSW	Reactor Shield Wall
RTIF	Reactor Trip and Isolation Function(s)
RT_{NDT}	Reference Temperature of Nil-Ductility Transition
RTP	Reactor Thermal Power
RW	Radwaste Building
RWBCR	Radwaste Building Control Room
RWBGA	Radwaste Building General Area
RWBHVAC	Radwaste Building HVAC
RWCU/SDC	Reactor Water Cleanup/Shutdown Cooling

Term	Definition
RWE	Rod Withdrawal Error
RWM	Rod Worth Minimizer
SA	Severe Accident
SAR	Safety Analysis Report
SB	Service Building
S/C	Digital Gamma-Sensitive GM Detector
SC	Suppression Chamber
S/D	Scintillation Detector
S/DRSRO	Single/Dual Rod Sequence Restriction Override
S/N	Signal-to-Noise
S/P	Suppression Pool
SAS	Service Air System
SB&PC	Steam Bypass and Pressure Control System
SBO	Station Blackout
SBWR	Simplified Boiling Water Reactor
SCEW	System Component Evaluation Work
SCRRI	Selected Control Rod Run-in
SDC	Shutdown Cooling
SDM	Shutdown Margin
SDS	System Design Specification
SEOA	Sealed Emergency Operating Area
SER	Safety Evaluation Report
SF	Service Water Building
SFP	Spent fuel pool
SIL	Service Information Letter
SIT	Structural Integrity Test
SIU	Signal Interface Unit
SJAE	Steam Jet Air Ejector
SLC	Standby Liquid Control
SLCS	Standby Liquid Control System
SLMCPR	Safety Limit Minimum Critical Power Ratio
SMU	SSLC Multiplexing Unit
SOV	Solenoid Operated Valve
SP	Setpoint
SPC	Suppression Pool Cooling
SPDS	Safety Parameter Display System
SPTMS	Suppression Pool Temperature Monitoring Subsystem of Containment Monitoring System
SR	Surveillance Requirement
SRM	Source Range Monitor
SRNM	Startup Range Neutron Monitor

Term	Definition
SRO	Senior Reactor Operator
SRP	Standard Review Plan
SRS	Software Requirements Specification
SRSRO	Single Rod Sequence Restriction Override
SRSS	Sum of the squares
SRV	Safety Relief Valve
SRVDL	Safety relief valve discharge line
SSAR	Standard Safety Analysis Report
SSC(s)	Structure, System and Component(s)
SSE	Safe Shutdown Earthquake
SSLC	Safety System Logic and Control
SSPC	Steel Structures Painting Council
ST	Spare Transformer
STP	Sewage Treatment Plant
STRAP	Scram Time Recording and Analysis Panel
STRP	Scram Time Recording Panel
SV	Safety Valve
SWH	Static water head
SWMS	Solid Waste Management System
SY	Switch Yard
TAF	Top of Active Fuel
TASS	Turbine Auxiliary Steam System
TB	Turbine Building
TBCE	Turbine Building Compartment Exhaust
TEAS	Turbine Building Air Supply
TBE	Turbine Building Exhaust
TBLOE	Turbine Building Lube Oil Area Exhaust
TBS	Turbine Bypass System
TBHV	Turbine Building HVAC
TBV	Turbine Bypass Valve
TC	Training Center
TCCWS	Turbine Component Cooling Water System
TCS	Turbine Control System
TCV	Turbine Control Valve
TDH	Total Developed Head
TEMA	Tubular Exchanger Manufacturers' Association
TFSP	Turbine first stage pressure
TG	Turbine Generator
TGSS	Turbine Gland Seal System
THA	Time-history accelerograph

Term	Definition
TLOS	Turbine Lubricating Oil System
TLU	Trip Logic Unit
TMI	Three Mile Island
TMSS	Turbine Main Steam System
TRM	Technical Requirements Manual
TS	Technical Specification(s)
TSC	Technical Support Center
TSI	Turbine Supervisory Instrument
TSV	Turbine Stop Valve
UBC	Uniform Building Code
UHS	Ultimate heat sink
UL	Underwriter's Laboratories Inc.
UPS	Uninterruptible Power Supply
USE	Upper Shelf Energy
USM	Uniform Support Motion
USMA	Uniform support motion response spectrum analysis
USNRC	United States Nuclear Regulatory Commission
USS	United States Standard
UV	Ultraviolet
V&V	Verification and Validation
Vac / VAC	Volts Alternating Current
Vdc / VDC	Volts Direct Current
VDU	Video Display Unit
VW	Vent Wall
VWO	Valves Wide Open
WD	Wash Down Bays
WH	Warehouse
WS	Water Storage
WT	Water Treatment
WW	Wetwell
XMFR	Transformer
ZPA	Zero period acceleration

11. RADIOACTIVE WASTE MANAGEMENT

11.1 SOURCE TERMS

The information provided in this section defines the radioactive source terms in the reactor water and steam which serve as design bases for the gaseous, liquid and solid radioactive waste management systems.

Radioactive source term data for boiling water reactors has been incorporated in American National Standard ANSI/ANS 18.1 (Reference 11.1-1). This standard provides bases for estimating typical concentrations of the principal radionuclides that may be anticipated over the lifetime of a BWR plant. The source term data is based on the cumulative industry experience at operating BWR plants, including measurements at several stations. It therefore reflects the influence of a number of observations made during the transition period from operation with fuel of older designs to operation with fuel of current improved designs. The source terms specified in this section were obtained by applying the procedures of Reference 11.1-1 for estimation of typical source terms and adjusting the results upward as appropriate to assure conservative bases for design.

The various radionuclides included in the design basis term have been categorized as fission products or activation products and tabulated in the subsections that follow. The lists do not necessarily include all radionuclides that may be detectable or theoretically predicted to be present.

Those that have been included are considered to be potentially significant with respect to one or more of the following criteria:

- plant equipment design,
- shielding design,
- understanding system operation and performance,
- measurement practicability.

The values provided in this section are not valid for calculation of environmental releases. Ratio factors are given in Table 11.1-1 and are discussed in Chapter 12.2.2.

11.1.1 Fission Products

Noble Radiogas Fission Products

Typical concentrations of the 13 principal noble gas fission products as observed in steam flowing from the reactor vessel are provided in the Source Term Standard ANSI/ANS-18.1 (Reference 11.1-1). Concentrations in the reactor water are considered negligible, because all of the gases released to the coolant are assumed to be rapidly transported out of the vessel with the steam and removed from the system with the other non-condensables in the main condenser. As a result of the immediate removal of all the gases, the expected relative mix of gases does not depend on the reactor design.

The design basis noble gas source term mixture is from Reference 11.1-1, and the total of the release rates of the 13 noble gases from the vessel. The noble radiogas source term rate after 30-minute decay has been used as a conventional measure of the fuel leakage rate, because it is conveniently measurable and was consistent with the nominal 30-minute offgas holdup system used on a number of early plants. A design basis noble gas release rate of 3,700 MBq/sec (100,000 µCi/sec) at 30 minutes decay has historically been used for the design of the gaseous waste treatment systems in BWR plants (Reference 11.1-2) with satisfactory results. It was selected on the basis of operating experience with consideration given to several judgmental factors, including the implications to environmental releases, system contamination, and building air contamination. The design basis noble radiogas source terms are presented in Table 11.1-2.

Radioiodine Fission Products

For many years, design basis radioiodine source terms for BWRs have been specified to be consistent with an I^{131} leak rate of 26 MBq/sec (700 µCi/sec) from the fuel (Reference 11.1-2). Experience indicated that I^{131} leakage rates this high would be approached only during operation with substantial fuel cladding defects. It would not be anticipated that full power operation would continue for any significant period of time with fuel cladding defects as severe as might be indicated by I^{131} leakage in excess of 26 MBq/sec (700 µCi/sec).

The design basis reactor water radioiodine concentrations are based on the relative mix of radioiodines in reactor water predicted by the data of Reference 11.1-1 with magnitudes increased such that the I^{131} concentration is consistent with the Table 11.1-1 release rate from the fuel based upon shortened fuel. This provides a substantial margin relative to the expected I^{131} release rate shown in Table 11.1-1. Reference 11.1-1 specifies expected concentrations of the 5 principal radioiodines in reactor water for a reference BWR design and provides bases for adjusting the concentrations for plants with relevant plant parameters that do not match those of the reference plant. The concentration adjustment factors were calculated as described in Subsection 12.2.2 using the plant parameters in Table 11.1-3. The scale factor required to increase the concentration of I^{131} from the concentration calculated using Reference 11.1-1 to the design basis value is shown in Table 11.1-1. The design basis concentrations are presented in Table 11.1-4.

The ratio of concentration in reactor steam to concentration in reactor water (carryover ratio) is taken to be 0.02 for radioiodines (Reference 11.1-1). Consequently, the design basis concentrations of radioiodines in steam are defined by multiplying the values of Table 11.1-4 by the factor 0.02.

Other Fission Products

This category includes all fission products other than noble gases and iodines and also includes transuranic nuclides. Some of the fission products are noble gas daughter products that are produced in the steam and condensate system. The only transuranic which is detectable in significant concentrations is Np^{239}. Concentrations of those radionuclides that are typically observable in the coolant are provided in Reference 11.1-1 for a Reference BWR plant. The Reference plant concentrations are adjusted to obtain estimates for the ESBWR plant by using the procedure described in Subsection 11. 1.3 and appropriate data from Table 11.1-3. In order to assure conservative design basis concentrations for the ESBWR, the results were increased by the same factor used to obtain design basis radioiodine concentrations. The design basis reactor water concentrations are presented in Table 11.1-5. The ratio of concentration in steam to concentration in water (carryover) for these nuclides is expected to be less than 0.001. The design basis concentrations in steam are obtained by multiplying the values in Table 11.1-5 by 0.001.

11.1.2 Activation Products

Coolant Activation Products

The coolant activation product of primary importance in BWRs is N^{16}. ANSI/ANS-18.1 (Reference 11.1-1) specifies a concentration of 1.85 MBq/gm (50 µCi/gm) in steam leaving the reactor vessel for plants without Hydrogen Water Chemistry (HWC). Plants with HWC are specified at 9.25 MBq/gm (250 µCi/gm). This HWC concentration is used as the design basis N^{16} concentration in steam for ESBWR. This is treated as essentially independent of reactor design because both the production rate of N^{16} and the steam flow rate from the vessel are assumed to vary in direct proportion to reactor thermal power. It should be noted that a portion of the source term traditionally identified as "N^{16}" actually represents C^{15}. To the extent that C^{15} is present, it is no more than about ~ 0.55 MBq/gm (15 µCi/gm). Historically, gross gamma dose rate measurements made to confirm the magnitude of the N^{16} concentration have included responses to gamma rays from C^{15}. Use of the combined "N^{16}" source term in shielding design introduces additional conservatism because the C^{15} component has a 2.45 second half-life, and therefore decays more rapidly with transport time through the system than N^{16}, which has a 7.1 second half-life.

The design basis N^{16} concentrations in steam and reactor water are shown in Table 11.1-6. Reference 11.1-1 gives the reactor water concentration at the recirculation system. Because the ESBWR does not have an external recirculation loop, the reactor water concentration has been decay-corrected to the reactor core exit to obtain an estimated value shown in Table 11.1-1.

Noncoolant Activation Products

Radionuclides are produced in the coolant by neutron activation of circulating impurities and by corrosion of irradiated system materials. Typical reactor water concentrations for the principal activation products are contained in Reference 11.1-1. The values of Reference 11.1-1 were adjusted to ESBWR conditions by using the procedure described in Subsection 11.1. 3 and appropriate data from Table 11.1-3. These results were arbitrarily increased by the same factor used for the design basis radioiodine concentrations to obtain the conservative design basis reactor water concentrations shown in Table 11.1-7. The steam carryover ratio for these isotopes is estimated to be less than 0.001. A factor of 0.001 is applied to the Table 11.1-7 values to obtain the design basis concentrations in steam.

Tritium

Tritium is produced by activation of naturally occurring deuterium in the primary coolant and, to a lesser extent, as a fission product in the fuel (Reference 11.1-2). The tritium is primarily present as tritiated oxide (HTO). Because tritium has a long half-life (12 years) and is not affected by cleanup processes in the system, the concentration is controlled by the rate of loss of water from the system by evaporation or leakage. All plant process water and steam have a common tritium concentration. The concentration reached depends on the actual water loss rate; however, References 11.1-1 and 11.1-3 both specify a typical concentration of 370 Bq/gm (0.01 µCi/gm) that is stated in Reference 11.1-3 to be based on BWR experience adjusted to account for liquid recycle. This value is taken to be applicable for the ESBWR.

Argon-41

Argon-41 is produced in the reactor coolant as a consequence of neutron activation of naturally occurring Argon-40 in air that is entrained in the feedwater. The Argon-41 gas is carried out of the vessel with the steam and stripped from the system with the non-condensables in the main condenser. Observed Argon-41 levels are highly variable due to the variability in air in-leakage rates into the system. Reference 11.1-3 specifies an Argon-41 release rate from the vessel of 1.5 MBq/sec (40 µCi/sec) for a 3400 MW Reference BWR. This value bounded the available experimental database. Based on adjusting to the ESBWR thermal power, a design basis Argon-41 release rate specified for the ESBWR is shown in Table 11.1-1.

11.1.3 Radionuclide Concentration Adjustment

In order to determine the estimated concentrations of radionuclides in the groups classified as iodines, other non-volatile fission products, and non-coolant activation products using the ANSI/ANS-18.1 Source Term Standard (Reference 11.1-1), it is necessary to apply appropriate adjustment factors to the Reference Plant concentrations provided in the Standard.

Equilibrium concentrations in reactor water are assumed to satisfy the relationship:

$$C = \frac{S}{M(\lambda + R)} \qquad (11.1\text{-}1)$$

where:

C = radionuclide concentration

S = radionuclide input rate to coolant

M = reactor water mass

λ = radionuclide decay constant

R = sum of removal rates of the radionuclide from the system.

Consequently, if the radionuclide input rate is taken to depend primarily on the reactor thermal power, the adjustment factors to be applied to the Reference Plant reactor water concentrations are given by:

$$\text{Adjustment Factor} = \frac{PM_r(\lambda + R_r)}{P_r M(\lambda + R)} \qquad (11.1\text{-}2)$$

where the subscript "r" refers to the Reference Plant, P is the reactor thermal power and M, λ, and R are as defined above.

The removal rate from the system is the sum of the removal rates due to the Reactor Water Cleanup System and the condensate demineralizer and is given by:

$$R = \frac{F_c E_c + F_s ABE_s}{M} \qquad (11.1\text{-}3)$$

where:

F_c = cleanup system flow rate

E_c = fraction of radionuclide removed in cleanup demineralizer

F_s = steam flow rate

A = ratio of radionuclide concentration in steam to concentration in water (carryover ratio)

B = fraction of radionuclide in steam which is circulated through the condensate demineralizer

E_s = fraction of radionuclide removed in condensate demineralizer.

The Reference Plant and ESBWR plant parameters and the nuclide-dependent removal rate parameters used for the ESBWR are shown in Table 11.1-3. The nuclide-dependent parameters are the same as those used for the Reference Plant except for the fraction circulated through the condensate demineralizer.

11.1.4 Fuel Fission Production Inventory

Fuel fission product inventory information is used in establishing fission product source terms for accident analysis and is discussed in Chapter 15.

11.1.5 Process Leakage Sources

Process leakage results in potential release of noble gases and other volatile fission products via ventilation systems. Liquid from process leaks is collected and routed to the liquid-solid radwaste system. With the effective process offgas treatment systems now in use, the ventilation releases are relatively significant contributions to total plant releases.

Leakage of fluids from the process system results in the release of radionuclides into plant buildings. In general, the noble radiogases remain airborne and are released to the atmosphere with little delay via the building ventilation exhaust ducts. Other radionuclides partition between air and water and may plate-out on metal surfaces, concrete, and paint. Radioiodines are found in ventilation air as methyl iodide and as inorganic iodine (particulate, elemental, and hypoiodous acid forms).

As a consequence of normal steam and water leakage into the drywell, equilibrium drywell concentrations exist during normal operation. Purging of this activity from the drywell to the environment occurs via the drywell purge system, which can be routed and processed through a charcoal filtration system and makes minor contributions to total plant releases.

Airborne release data from BWR building ventilation systems and the main condenser mechanical vacuum pump have been compiled and evaluated in Reference 11.1-4, which contains data obtained by utility personnel and from special in-plant studies of operating BWR plants by independent organizations and by GE Nuclear Energy. Releases due to process leakage are reflected in the airborne release estimates discussed in Section 12.2..2.

11.1.6 References

11.1-1 ANSI/ANS, “American National Standard Radioactive Term for Normal Operation of Light Water Reactors,” ANSI/ANS-18.1-1999.

11.1-2 General Electric Company, “Technical Derivation of BWR 1971 Design Basis Radioactive Material Source Terms,” NEDO-10871, March 1973.

11.1-3 USNRC, “Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors,” NUREG-0016, Revision 1, January 1979.

11.1-4 General Electric Company, “Airborne Releases From BWRs for Environmental Impact Evaluations,” NEDO-21159, March 1976.

Table 11.1-1

Source Term Design Basis Parameters

Parameter	Value
Total of the release rates of the 13 noble gases (30minute decay reference, t30)	3700 MBq/sec (100,000 μCi/sec)
Normal operational noble gas release rate (t30)	740 MBq/sec (20,000μCi/sec)
Design basis I-131 radioiodine core release rate	26 MBq/sec (700 μCi/sec)
Expected I-131 radioiodine core release rate	3.7 MBq/sec (100- μCi/sec)
I^{131} concentration scale factor	5
Reactor core exit N^{16} concentration	1.85 MBq/gm (50 μCi/gm) w/o HWC 9.25 MBq/gm (250 μCi/gm) w/HWC
Design Basis $Argon^{41}$ release rate	2.0 MBq/sec (53 μCi/sec)

Table 11.1-2

Design Basis Noble Radiogas Source Terms in Steam

Isotope	**Decay Constant** (per hour)	**Steam Concentration** (MBq/gm)	(μCi/gm)	**Source Term at t=30min** (MBq/sec)	(μCi/sec)
Kr-83m	3.73E-1	5.4E-05	1.5E-03	1.1E+02	2.9E+03
Kr-85m	1.55E-1	9.1E-05	2.5E-03	2.0E+02	5.5E+03
Kr-85	7.37E-6	3.6E-07	9.8E-06	8.9E-01	2.4E+01
Kr-87	5.47E-1	3.0E-04	8.1E-03	5.6E+02	1.5E+04
Kr-88	2.48E-1	3.0E-04	8.1E-03	6.5E+02	1.7E+04
Kr-89	1.32E+1	1.9E-03	5.2E-02	6.4E+00	1.7E+02
Xe-131m	2.41E-3	3.0E-07	8.1E-06	7.3E-01	2.0E+01
Xe-133m	1.30E-2	4.5E-06	1.2E-04	1.1E+01	2.9E+02
Xe-133	5.46E-3	1.3E-04	3.4E-03	3.1E+02	8.4E+03
Xe-135m	2.72E+0	4.0E-04	1.1E-02	2.5E+02	6.8E+03
Xe-135	7.56E-2	3.5E-04	9.4E-03	8.1E+02	2.2E+04
Xe-137	1.08E+1	2.4E-03	6.4E-02	2.6E+01	6.9E+02
Xe-138	2.93E+0	1.4E-03	3.7E-02	7.7E+02	2.1E+04
Totals		7.3E-03	2.0E-01	3.7E+03	1.0E+05

Table 11.1-3

Calculational Parameters For Source Term Adjustment

A. Plant Parameters for Source Term Adjustment		
Parameter	**Reference Plant**	**ESBWR**
Thermal Power, MWt	3400	4500
Reactor Water Mass, kg	1.7E+5	6.74E+5
Cleanup System Flow Rate, kg/hr	5.8E+4	1.93E+5
Steam Flow Rate, kg/hr	6.8E+6	1.93E+7
Ratio of Condensate Demineralizer Flow Rate to Steam Flow Rate.	1	1

B. Removal Parameters for Source Term Adjustment			
Parameter	**Iodines**	**Rb, Cs**	**All Others**
Fraction removed by cleanup system	0.9	0.5	0.9
Fraction removed by condensate demineralizers	0.9	0.5	0.9
Ratio of concentration in steam and reactor water	0.02	0.001	0.001
Fraction of radionuclides in steam treated by condensate demineralizer.	1	1	1

Table 11.1-4

Design Basis Iodine Radioisotopes in Reactor Water and Steam

	Decay Constant	Water Concentration		Steam Concentration	
Isotope	(per hour)	(MBq/gm)	(μCi/gm)	(MBq/gm)	(μCi/gm)
I-131	3.59E-3	3.9E-04	1.1E-02	7.9E-06	2.1E-04
I-132	3.03E-1	3.7E-03	9.9E-02	7.4E-05	2.0E-03
I-133	3.33E-2	2.7E-03	7.2E-02	5.3E-05	1.4E-03
I-134	7.91E-1	6.8E-03	1.8E-01	1.4E-04	3.7E-03
I-135	1.05E-1	3.8E-03	1.0E-01	7.6E-05	2.1E-03

Table 11.1-5

Design Basis Non-volatile Fission Products In Reactor Water

	Decay Constant	**Concentration**	
Isotope*	(per hour)	(MBq/gm)	(μCi/gm)
Rb-89	2.74E+0	6.9E-04	1.9E-02
Sr-89	5.55E-4	1.7E-05	4.5E-04
Sr-90	2.81E-6	1.2E-06	3.1E-05
Y-90	2.81E-6	1.2E-06	3.1E-05
Sr-91	7.31E-2	6.4E-04	1.7E-02
Sr-92	2.56E-1	1.5E-03	4.1E-02
Y-91	4.93E-4	6.6E-06	1.8E-04
Y-92	1.96E-1	9.3E-04	2.5E-02
Y-93	6.80E-2	6.4E-04	1.7E-02
Zr-95/Nb-95	4.41E-4	1.3E-06	3.6E-05
Mo-99/Tc-99m	1.05E-2	3.3E-04	8.9E-03
Ru-103/Rh-103m	7.29E-4	3.3E-06	8.9E-05
Ru-106/Rh-106	7.83E-5	5.0E-07	1.3E-05
Te -129m	8.65E-4	6.6E-06	1.8E-04
Te-131m	2.31E-2	1.6E-05	4.4E-04
Te-132	8.89E-3	1.6E-06	4.5E-05
Cs-134	3.84E-5	4.5E-06	1.2E-04
Cs-136	2.22E-3	3.0E-06	8.0E-05
Cs-137/Ba-137m	2.63E-6	1.2E-05	3.2E-04
Cs-138	1.29E+0	1.4E-03	3.8E-02
Ba-140/La-140	2.26E-3	6.6E-05	1.8E-03
Ce-141	8.88E-4	5.0E-06	1.3E-04
Ce-144/Pr-144	1.02E-4	5.0E-07	1.3E-05
Np-239	1.24E-2	1.3E-03	3.6E-02

* Nuclides shown as pairs are assumed to be in secular equilibrium. The parent decay constant and concentration are shown.

Table 11.1-6

Design Basis N^{16} Concentrations in Reactor Water and Steam

Isotope	Half-Life	Steam Concentration* (MBq/gm)	Steam Concentration* (μCi/gm)	Reactor Water Concentration** (MBq/gm)	Reactor Water Concentration** (μCi/gm)
N-16	7.13 sec	1.85	50	2.2	60

* During operation with hydrogen water chemistry, increase this value by a factor of five.

** Valid at core exit.

Table 11.1-7

Design Basis Non-coolant Activation Products in Reactor Water

	Decay Constant	Concentration	
Isotope	(per hour)	(MBq/gm)	(μCi/gm)
Na-24	4.63E-2	3.2E-04	8.7E-03
P-32	2.02E-3	6.6E-06	1.8E-04
Cr-51	1.04E-3	5.0E-04	1.3E-02
Mn-54	9.53E-5	5.8E-06	1.6E-04
Mn-56	2.69E-1	3.8E-03	1.0E-01
Fe-55	3.04E-5	1.7E-04	4.5E-03
Fe-59	6.33E-4	5.0E-06	1.3E-04
Co-58	4.05E-4	1.7E-05	4.5E-04
Co-60	1.50E-5	3.3E-05	8.9E-04
Ni-63	7.90E-7	1.7E-07	4.5E-06
Cu-64	5.42E-2	4.8E-04	1.3E-02
Zn-65	1.18E-4	1.7E-04	4.5E-03
Ag-110M	1.16E-4	1.7E-07	4.5E-06
W-187	2.90E-2	4.9E-05	1.3E-03

11.2 LIQUID WASTE MANAGEMENT SYSTEM

The ESBWR Liquid Waste Management System (LWMS) is designed to control, collect, process, handle, store, and dispose of liquid radioactive waste generated as the result of normal operation, including anticipated operational occurrences.

The LWMS is housed in the radwaste building and consists of the following four subsystems:

- equipment (low conductivity) drain subsystem;
- floor (high conductivity) drain subsystem;
- chemical drain subsystem;
- detergent drain subsystem;

A LWMS Process Diagram depicting all four subsystems is provided in Figure 11.2-1. A conceptual radwaste building general arrangement is provided in Figures 1.2-21 thru 1.2-25. The LWMS equipment codes and component capacities are provided in Tables 11.2-1, 11.2-2a, 11.2-2b, and 11.2-2c, respectively. The normal and maximum daily inputs, and process decontamination factors for the LWMS subsystems are provided in Tables 11.2-3 and 11.2-4, respectively.

The equipment and floor drainage collection system, a major input source to the LWMS, is described in Subsection 9.3.3.

Process and effluent radiological monitoring and sampling systems are described in Section 11.5.

11.2.1 Design Bases

Safety Design Bases

The LWMS has no safety-related function.

Power Generation Design Bases

- The LWMS has the capability to process the maximum anticipated quantities of liquid waste without impairing the operation or availability of the plant during both normal and expected occurrence conditions, satisfying the requirements of 10 CFR 20 and 10 CFR 50 (see Table 11.2-4 for time to process maximum inputs).
- Alternate process subsystem cross-ties and adequate storage volumes are included in the LWMS design to provide for operational and anticipated surge waste volumes.
- The LWMS is designed so that no potentially radioactive liquids can be discharged to the environment unless they have first been monitored and diluted as required. Off-site radiation exposures on an annual average basis are within the limits of 10 CFR 20 and 10 CFR 50.
- The LWMS is designed to meet the requirements of General Design Criterion (GDC) 60 and Regulatory Guide 1.143.
- The LWMS is designed to keep the exposure to plant personnel “as low as reasonably achievable” (ALARA) during normal operation and plant maintenance, in accordance with Regulatory Guide 8.8.

- The seismic category, quality group classification, and corresponding codes and standards that apply to the design of the LWMS are discussed in Section 3.2.
- All atmospheric liquid radwaste tanks are provided with an overflow connection at least the size of the largest inlet connection. The overflow is connected below the tank vent and above the high level alarm setpoint. Each collection tank room is designed to contain the maximum liquid inventory in the event that the tank ruptures.
- An evaluation is included in Chapter 12 to show that the proposed systems are capable of controlling releases of radioactive materials within the numerical design objectives of Appendix I to 10 CFR 50.
- An evaluation is included in Chapter 12 to show that the proposed systems have sufficient capacity, redundancy, and flexibility to meet the concentration limits of 10 CFR 20 during periods of equipment downtime and during operation at design basis fuel leakage.

Process and effluent radiological monitoring systems are described in Section 11.5.

11.2.2 System Description

11.2.2.1 Summary Description

The LWMS collects, monitors, processes, stores, and disposes of potentially radioactive liquid waste collected throughout the plant.

The equipment and floor drainage systems are described in Section 9.3.

Potentially radioactive liquid wastes are collected in tanks located in the radwaste building. System components are designed and arranged in shielded enclosures to minimize exposure to plant personnel during operation, inspection, and maintenance. Tanks, processing equipment, pumps, valves, and instruments that may contain radioactivity are located in controlled access areas.

The LWMS normally operates on a batch basis. Provisions for sampling at important process points are included. Protection against accidental discharge is provided by detection and alarm of abnormal conditions and by administrative controls.

The LWMS is divided into several subsystems, so that the liquid wastes from various sources can be segregated and processed separately, based on the most economical and efficient process for each specific type of impurity and chemical content. Cross-connections between subsystems provide additional flexibility in processing the wastes by alternate methods and provide redundancy if one subsystem is inoperative.

11.2.2.2 System Operation

The LWMS consists of the following four process subsystems:

Equipment (Low Conductivity) Drain Subsystem

The equipment drain collection tanks receive low conductivity inputs from various sources within the plant. These waste inputs have a high chemical purity and are processed on a batch basis. The equipment drain subsystem consists of three collection tanks and collection pumps, a mobile based Hollow Fiber Filter (HFF) and Deep-Bed Ion Exchanger system including organic material pre-treatment equipment, an intermediate tank/pump, and two sample tanks and sample pumps. One collection tank is normally used as a surge tank that can collect waste from the low conductivity waste and/or high conductivity waste. Cross-connections with the floor drain subsystem allows processing through the mobile system for floor drain treatment.

Mobile based chemical addition equipment is provided to add chemical agent(s) for recovering the performance of the HFF System. The equipment provides for addition of chemical agent(s) for the Reverse Osmosis System (RO) in the floor drain subsystem.

A strainer or filter is provided downstream of the last ion exchanger in series to collect any crud and resin fines that may be present.

The process effluents are collected in one of the two sample tanks for chemical and radioactivity analysis. If acceptable, the tank contents are returned to the condensate storage tank for plant reuse. A recycle line from the sample tanks allows the sampled effluents that do not meet water quality requirements to be pumped back to an Equipment (Low Conductivity) Drain Collection Tank or Floor (High Conductivity) Drain Collection Tank for additional processing. If the plant condensate inventory is high, the sampled process effluent may be discharged.

The HFF is backwashed periodically to maintain filtration capacity. Backwash waste is discharged to a low activity phase separator. Spent deep-bed ion exchanger resin is discharged to a low activity spent resin holdup tank as a slurry.

Floor (High Conductivity) Drain Subsystem

The floor drain collection tanks receive high conductivity waste inputs from various floor drain sumps in the reactor building, turbine building, and radwaste building. The floor drain collection tanks also receive waste input from chemical drain collection tank.

The floor drain subsystem consists of two floor drain collection tanks and collection pumps, a mobile based Reverse Osmosis (RO) and Deep-Bed Ion Exchanger System including suspended solid pre-treatment equipment, an intermediate tank/pump and two sample tanks and sample pumps. The waste collected in the floor drain collection tanks are processed on a batch basis. Cross-connections with the equipment drain subsystem also allow for processing through that subsystem.

Additional collection capacity is also provided by one additional equipment drain collection tank that is shared with the equipment drain subsystem.

A strainer or filter is provided downstream of the last ion exchanger in series to collect any crud and resin fines that may be present.

The floor drain sample tanks collect the process effluent, so that a sample may be taken for chemical and radioactivity analysis before discharging or recycling. The discharge path depends on the water quality, dilution stream availability and plant water inventory. Off-standard quality effluent can be recycled to floor drain collection tanks or equipment drain collection tanks. If the treatment effluent meets water quality standards and if the water inventory permits it to be recycled, the processed floor drain effluent can be recycled to the condensate storage tank or discharged off-site.

The liquid waste is concentrated in the RO system and is periodically discharged to a concentrated waste tank. Spent deep-bed ion exchanger resin is discharged to a low activity spent resin holdup tank as a slurry.

The capability exists to accept used condensate polishing resin in a Condensate Resin Holdup Tank. The used condensate polishing resin from Condensate Purification System is transferred to the Condensate Resin Holdup Tank prior to use in the pre-treatment deep-bed ion exchanger in the floor drain subsystem.

Chemical Drain Subsystem

The chemical waste collected in the chemical drain collection tank consists of laboratory wastes and decontamination solutions. After accumulating in the chemical drain collection tank, chemical agents may be added to the chemical drain by mobile-based chemical pre-treatment equipment if necessary and the pre-treated chemical drain is transferred to floor drain collection tanks for further processing. Chemical pre-treatment operation is typically a neutralization process. A sample is then taken and if discharge standards are met, then the waste may be discharged off-site. A cross-connection with the detergent drain subsystem is also provided.

Detergent Drain Subsystem

Waste water containing detergent from the controlled laundry and personnel decontamination facilities and decontamination waste water from the reactor building or turbine building throughout the plant is collected in the detergent drain collection tanks. The detergent drain subsystem consists of two detergent drain collection tanks and collection pumps, a mobile-based detergent drain filter and charcoal filter system including organic material pre-treatment equipment, an intermediate tank/pump, and two sample tanks and sample pumps. The detergent wastes are processed through a suspended solid removal process and organic material removal process and collected in sample tanks. A sample is then taken and if discharge standards are met, then the waste is discharged off-site. Off-standard quality water can either be recycled for further processing to the detergent collection tank or to the floor drain collection tank. A cross-connection with the chemical drain collection subsystem is also provided.

11.2.2.3 Detailed System Component Description

The LWMS consists of permanently installed tanks, pumps, pipes, valves, and instruments, and mobile systems for waste processing. Mobile systems provide an operational flexibility and maintainability to support plant operation. The major components of the LWMS are as follows:

Pumps

Two types of pumps are utilized in the LWMS.

The LWMS process pumps are centrifugal pumps constructed of materials suitable for their intended service.

Neutralization chemicals in the LWMS are added with reciprocating positive displacement pumps (or functionally similar pumps). These pumps are constructed of materials suitable for their intended service.

Tanks

Tanks are sized to accommodate the expected volumes of waste generated in the upstream systems that feed waste into the LWMS for processing. The tanks are constructed of stainless steel to provide a low corrosion rate during normal operation. They are provided with mixing eductors and/or air spargers. The capability exists to sample all LWMS collection and sample tanks. All LWMS tanks are vented through a filtration unit and eventually discharged into the plant vent. The LWMS tanks are designed in accordance with the equipment codes listed in Table 11.2-1.

All atmospheric liquid radwaste tanks are provided with an overflow connection at least the size of the largest inlet connection. The overflow is connected below the tank vent and above the high level alarm setpoint. Each collection tank room is designed to contain the maximum liquid inventory in the event that the tank ruptures.

Mobile Systems

Mobile Systems for equipment drain processing

The equipment drain mobile system utilizes non-precoat type Hollow Fiber Filter (HFF) for removing suspended solid and radioactive particulate material and charcoal filters for organic material removal. Backwash operation for HFF is performed when the differential pressure of HFF exceeds a preset limit. HFF backwash waste is discharged to a low activity phase separator. A charcoal filter is located upstream of HFF for the purpose of removing organic material, which may cause fouling of the HFF. Spent charcoal is packaged directly into the container when the differential pressure exceeds a preset limit or waste quality of the effluent from the charcoal filter exceeds a preset value.

The equipment drain ion exchangers following the HFF are of the mixed-bed type. Exhausted resins are sluiced to the low activity spent resin holdup tank when some chosen effluent purity parameter (such as conductivity) exceeds a preset limit or upon high differential pressure. Fine mesh strainers with backwashing connections are provided in the ion exchange vessel discharge and in the downstream piping to prevent resin fines from being carried over to the sampling tanks.

The mobile system is skid-mounted and is designed and configured for relatively easy installation and process reconfiguration. In-plant supply and return connections from permanently installed equipment to the mobile system are provided to keep operational flexibility.

Mobile Systems for floor drain and chemical drain processing

Floor drain and chemical drain wastes are more complex to process than equipment drains. The floor drain mobile system utilizes pre-filtration equipment for removing suspended solids and organic impurities, Reverse Osmosis System (RO) for removing ionic impurities, and finally deep-bed ion exchangers for polishing.

The pre-filtrated liquid waste is collected into the feed tank of the RO System. The feed tank serves as a front-end supply tank to the process. The liquid waste is transferred to the RO unit via a booster pump. The RO unit uses membrane tubes that are made of a semi-permeable material. When pressure is applied to the feed side of the membrane, the solution passes through the membrane (permeates) and the solids and high molecular wastes are rejected. The rejected solids and ionic impurities are returned to the feed tank and the final permeate is polished by deep-bed ion exchangers. The floor drain ion exchangers following the RO are of the mixed-bed type. Exhausted resins are sluiced to the spent resin tank when some chosen effluent purity parameter (such as conductivity) exceeds a preset limit or upon high differential pressure. Fine mesh strainers with backwashing connections are provided in the ion exchange vessel discharge and in the downstream piping to prevent resin fines from being carried over to the sampling tanks.

The chemical drain pre-treatment unit performs a pre-conditioning of chemical waste, such as pH adjustment, prior to processing in the RO system.

The mobile system is of a skid-mounted design and configured for relatively easy installation and process reconfiguration. In-plant supply and return connections from permanently installed equipment to the mobile system are provided to ensure operational flexibility.

Mobile Systems for detergent drain processing

The detergent drain mobile system typically utilizes a charcoal filter to remove organics and a cartridge type filter to remove suspended solids. When the deferential pressure of the filter exceeds a preset value, the filter media is exchanged and the spent filter media is packaged as active solid waste.

The mobile system is of a skid-mounted design and configured for relatively easy installation and process reconfiguration. In-plant supply and return connections from permanently installed equipment to the mobile system are provided to ensure operational flexibility.

The mobile systems are located in the Liquid Waste Treatment System bay to allow truck access and mobile system skid loading and unloading. Modular shield walls are provided in the Radwaste Building to allow shield walls to be constructed to minimize exposure to personnel during operation and routine maintenance.

11.2.3 Safety Evaluation — Radioactive Releases

Safety Evaluation

The LWMS has no safety-related function. Failure of the system does not compromise any safety-related system or component nor does it prevent shutdown of the plant. No interface with the Class 1E electrical system exists.

Radioactive Releases

During liquid processing by the LWMS, radioactive contaminants are removed and the bulk of the liquid is purified and either returned to the condensate storage tank or discharged to the environment. The radioactivity removed from the liquid waste is concentrated in filter media ion exchange resins and concentrated waste. The decontamination factors (DFs) that are listed in Table 11.2-3 are in accordance with NUREG-0016, but are considered conservative values. The filter sludge, ion exchange resins and concentrated waste are sent to the Solid Waste Management System (SWMS) for further processing. If the liquid meets the purity requirements it is returned to the plant for condensate makeup. If the liquid is discharged, the activity concentration is consistent with the discharge criteria of 10 CFR 20 and dose commitment in 10 CFR 50, Appendix I.

The parameters and assumptions used to calculate releases of radioactive materials in liquid effluents and their bases are provided in Chapter 12.

Expected releases of radioactive materials by radionuclides in liquid effluents resulting from normal operation, including anticipated operational occurrences and from design basis fuel leakage are provided in Chapter 12.

A tabulation of the releases by radionuclides can be found in Chapter 12. The tabulation is for the total system and for each and includes indication of the effluent concentrations. The calculated concentrations in the effluents were within the concentration limits of 10 CFR 20; the doses resulting from the effluents are within the numerical design objectives of Appendix I to 10 CFR 50 and the dose limits of 10 CFR 20 as set forth in Chapter 12.

Dilution Factors

Refer to Section 12.2 for dilution factors used in evaluating the release of liquid effluents.

11.2.4 Testing and Inspection Requirements

The LWMS is given a pre-operational test as discussed in Chapter 14. Thereafter, portions of the systems are tested as needed.

During initial testing of the system, the pumps and mobile systems are performance tested to demonstrate conformance with design flows and process capabilities. An integrity test is performed on the system upon completion.

Provisions are made for periodic inspection of major components to ensure capability and integrity of the systems. Local display devices are provided to indicate all vital parameters required in routine testing and inspection.

11.2.5 Instrumentation Requirements

The LWMS is operated and monitored from the Radwaste Building Control Room. Major system parameters, i.e., tank levels, process flow rates, filter and ion exchanger differential pressure, ion exchanger effluent conductivity, etc., are indicated and alarmed as required to provide operational information and performance assessment. Key system alarms are repeated in the main control room.

Requirements for sampling are set forth in Subsection 9.3.2.

11.2.6 COL Information

None.

11.2.7 References

None.

Table 11.2-1

Equipment Codes (from Table 1, RG 1.143)*

Equipment	Design and Fabrication	Materials[1]	Welder Qualification and Procedures	Inspection and Testing
Pressure Vessels	ASME Code Section VIII, Div. 1 or Div.2	ASME Code Section II	ASME Code Section IX	ASME Code Section VIII, Div. 1 or Div.2
Atmospheric Tanks	ASME Code[2] Section III, Class 3, or API 650, or AWWA D-100	ASME Code[3] Section II	ASME Code Section IX	ASME Code[2] Section III, Class 3; or API 650, or AWWA D-100
0-15 psig Tanks	ASME Code[2] Section III, Class 3, or API 620	ASME Code[3] Section II	ASME Code Section IX	ASME Code[2] Section III, Class 3 or API 620
Heat Exchangers	ASME Code Section VIII, Div. 1 or Div.2 and TEMA	ASME Code Section II	ASME Code Section IX	ASME Code Section VIII, Div. 1 or Div.2
Piping and Valves	ANSI B31.3	ASTM and ASME Code Section II	ASME Code Section IX	ANSI B31.3
Pumps	API 610; API 674 ; API 675 ; or ASME BPVC Section VIII, Div.1 or Div.2 or Manufacturer's Standards[4]	ASTM A571-84 (1997) or ASME Code Section II or Manufacturer's Standards	ASME Code Section IX (as required)	ASME Code[2] Section III, Class 3; or Hydraulic Institute
Flexible Hoses and Hose Connections for MRWP	ANSI/ANS-40.37	ANSI/ANS-40.37	ANSI/ANS-40.37	ANSI/ANS-40.37

Notes:
(1) Manufacturer's material certificates of compliance with material specifications may be provided in lieu of certified material.
(2) ASME Code stamp, material traceability, and the quality assurance criteria of Appendix B to 10 CFR 50 are not required. Therefore, these components are not classified as ASME Code Section III, Class 3.
(3) Fiberglass-reinforced plastic tanks may be used in accordance with appropriate articles of Section 10 of the ASME Boiler and Pressure Vessel Code for applications at ambient temperature.
(4) Manufacturer's standard for the intended service. Hydrotesting should be at 1.5 times the design pressure.

* Per RG 1.143, all materials are in accordance of ASME Section II.

Table 11.2-2a

LWMS Component Capacity (Tanks)*

Component	Type**	Quantity	Nominal Capacity*** Liter (Gal) per Tank
Equipment Drain Collection Tanks	Vertical, Cylindrical	3	140,000 (36,988)
Equipment Drain Sample Tanks	Vertical, Cylindrical	2	140,000 (36,988)
Floor Drain Collection Tanks	Vertical, Cylindrical	2	130,000 (34,346)
Floor Drain Sample Tanks	Vertical, Cylindrical	2	130,000 (34,346)
Chemical Drain Collection Tank	Vertical, Cylindrical	1	4,000 (1,057)
Detergent Drain Collection Tanks	Vertical, Cylindrical	2	15,000 (3,963)
Detergent Drain Sample Tanks	Vertical, Cylindrical	2	15,000 (3,963)

* Per RG 1.143, all materials are in accordance of ASME Section II.

** Per RG 1.143, tank design and fabrication are in accordance with ASME Section III, Class 3; API 620; API 650 or AWWA D-100, depending on design requirements.

*** Nominal capacity refers to the total tank capacity.

Table 11.2-2b

LWMS Component Capacity (Pumps)*

Component	Type	Quantity	Nominal Capacity* Liters/Hour (gpm)
Equipment Drain Collection Pumps	Horizontal, Centrifugal	3	60,000 (264)
Equipment Drain Sample Pumps	Horizontal, Centrifugal	2	60,000 (264)
Floor Drain Collection Pumps	Horizontal, Centrifugal	2	55,000 (242)
Floor Drain Sample Pumps	Horizontal, Centrifugal	2	55,000 (242)
Chemical Drain Collection Pumps	Horizontal, Centrifugal	2	6,000 (26.4)
Detergent Drain Collection Pumps	Horizontal, Centrifugal	2	12,000 (52.8)
Detergent Drain Sample Pumps	Horizontal, Centrifugal	2	12,000 (52.8)

* Pump capacity refers to the minimum required capacity.

Table 11.2-2c

LWMS Component Capacity (Mobile Systems)

Component*	Type	Quantity**	Nominal Cap.
Mobile Systems for Equipment Drain Processing		1	20,000L/h (88gpm)
Equipment Drain Pre-Filter	Charcoal Filter or others		
Equipment Drain Filter	Hollow Fiber Filter		
Equipment Drain Ion Exchangers	Mixed Bed Type		
Equipment Drain Chemical Injection Unit	-		
Equipment Drain Intermediate Tank	Vertical, Cylindrical		
Equipment Drain Intermediate Pump	Horizontal, Centrifugal		
Mobile Systems for Floor Drain Processing		1	15,000L/h (66gpm)
Floor Drain Pre-Filters	Cartridge Type		
Floor Drain Reverse Osmosis (RO) unit	Reverse Osmosis (RO)		
Floor Drain Ion Exchangers	Mixed Bed Type		
Floor Drain Intermediate Tank	Vertical, Cylindrical		
Floor Drain Intermediate Pump	Horizontal, Centrifugal		
Mobile Systems for Chemical Drain Processing		1	-
Chemical Drain Neutralization Unit	-		
Mobile Systems for Detergent Drain Processing		1	2,000L/h (8.8gpm)
Detergent Drain Organic Pre-Treatment	Charcoal or others		
Detergent Drain Pre-Filter	Cartridge Type		
Detergent Drain Charcoal Filter	Charcoal Filter		

* Typical components are shown for each mobile system.
** This column shows mobile system quantity for each subsystem, not each component quantity.

Table 11.2-3

Decontamination Factors

Subsystems*	Filter	Reverse Osmosis	Ion-Exchanger	Total DF
Equipment (low conductivity)				
Drain Subsystem:				
Halogens	1	-	100 (10)**	1,000
Cs, Rb	1	-	10 (10)**	100
Other nuclides	1	-	100 (10)**	1,000
Floor (high conductivity)				
Drain Subsystem:				
Halogens	1	10	100 (10)**	10,000
Cs, Rb	1	10	2 (10)**	200
Other nuclides	1	10	100 (10)**	10,000
Chemical Drain Subsystem:				
Chemical drain is processed in Floor Drain Subsystem.				
Detergent Drain Subsystem:				
A DF of 1 is used for the detergent drain filter for all radionuclides.				

* From NUREG-0016 Revision 1, Table 1-5.
** For two ion exchangers in series, the DF for the second unit is given in parenthesis

Table 11.2-4

Probable Inputs to LWMS from Operational Occurrences

Subsystem	**Normal Liters/Day (Gal/Day)**	**Maximum Liters/Day (Gal/Day)**	Time Needed to Process Maximum Input (Hr)
Equipment (low conductivity) Drain Subsystem	65,000 (17,173)	125,000 (33,025)	6.3
Floor (high conductivity) Drain Subsystem	11,000 (2,906)	100,000 (26,420)	6.7
Chemical Drain Subsystem	3,000 (793)	3,000 (793)	0.2
Detergent Drain Subsystem	4,000 (1,057)	12,000 (3,170)	6.0

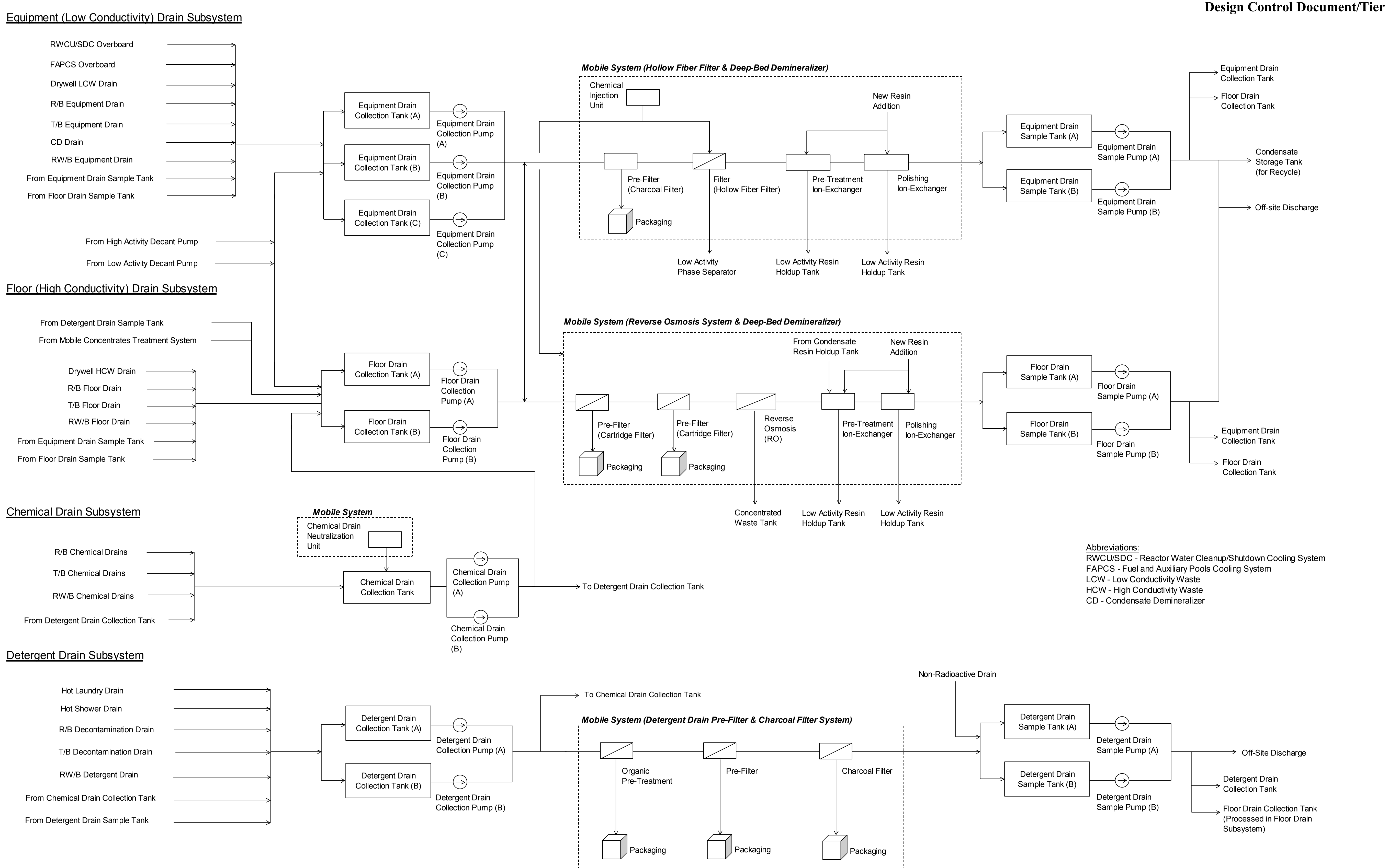


Figure 11.2-1. Liquid Waste Management System Process Diagram

11.3 GASEOUS WASTE MANAGEMENT SYSTEM

11.3.1 Design Bases

The objective of the gaseous waste management system is to process and control the release of gaseous radioactive effluents to the site environs so as to maintain the exposure of persons in unrestricted areas to radioactive gaseous effluents as low as reasonable achievable according to 10 CFR 50, Appendix I (Reference 11.3-1). This is accomplished while maintaining occupational exposure as low as reasonably achievable and without limiting plant operation or availability.

The two main sources of plant gaseous radioactive effluents are the building ventilation systems, which are discussed in Section 9.4 and the power cycle offgas system (Offgas System) that is described and reviewed in this section.

The Offgas System (OGS) provides for holdup and, thereby, decay of radioactive gases in the offgas from the main condenser evacuation system (Subsection 10.4.2) and consists of process equipment along with monitoring instrumentation and control components.

The OGS minimizes and controls the release of radioactive material into the atmosphere by delaying release of the offgas process stream initially containing radioactive isotopes of krypton, xenon, iodine, nitrogen, and oxygen. This delay, using activated charcoal absorber beds, is sufficient to achieve adequate decay before the process offgas stream becomes discharged from the plant.

The OGS design minimizes the explosion potential in the OGS through recombination of radiolytic hydrogen and oxygen under controlled conditions.

The gaseous effluent treatment systems are designed to limit the dose to off-site persons from routine station releases to significantly less than the limits specified in 10 CFR 20 (Reference 11.3-2) and to operate within the relevant limits specified in the plant-specific Technical Specifications.

As a conservative design basis for the OGS, an average annual noble radiogas source term (based on 30 minute decay) is assumed. The OGS System Design Parameters are shown in Table 11.3-1. The system is mechanically capable of processing three times the source term without affecting delay time of the noble gases. Also listed is the isotopic distribution at $t = 0$. Table 11.3-1 shows the xenon time delays with an assumed air in-leakage.

Using the given isotopic activities at the discharge of the OGS, the decontamination factor for each noble gas isotope can be determined. Section 11.1 presents source terms for normal operational and anticipated occurrence releases to the primary coolant. Tables in this section, if not designated otherwise, are based upon a design basis annual average offgas release rate (measured after 30 minutes decay from the core) of noble gases and I^{131} as shown in Table 11.3-1 and 12.2-15. For normal expected conditions, the leak rates and doses are expected to be less than one-fifth of the design basis numbers.

The average annual exposure at the site boundary during normal operation from all gaseous sources is not expected to exceed the dose objectives of 10 CFR 50, Appendix I, in terms of actual doses to actual persons (Refer to Section 12.2). The radiation dose design basis for the treated offgas is to provide sufficient holdup until the required fraction of the radionuclides has decayed with the daughter products retained by the charcoal.

The gaseous waste management system equipment is selected, arranged, and shielded to maintain occupational exposure as low as reasonably achievable in accordance with Nuclear Regulatory Commission Regulatory Guide 8.8.

The gaseous waste management system is designed to the requirements of the General Design Criteria 60 and 64.

A list of the OGS major equipment items, including materials, rates, process conditions, number of units supplied, and relevant design codes, is provided in Table 11.3-2.

The OGS is also designed to the requirements indicated in DCD section 3.2.

11.3.2 Offgas System Description

Process Functions

Major process functions of the OGS include the following:

- recombination of radiolytic hydrogen and oxygen into water to reduce the gas volume to be treated and the explosion potential in downstream process components;
- two-stage condensation of bulk water vapor first using condensate and then chilled water as the coolant reducing the gaseous waste stream temperature to the value shown in Table 11.3-1;
- dynamic adsorption of krypton and xenon isotopes on charcoal at the approximate temperature shown in Table 11.3-1;
- monitoring of offgas radioactivity levels and hydrogen gas content;
- release of processed offgas to the atmosphere; and
- discharge of liquids to the condenser and Liquid Waste Management System.

Process Equipment

Major process equipment of the OGS consists of the following:

- recombiners, including a preheater section, a catalyst section, and a condenser section;
- cooler-condensers;
- activated charcoal adsorbers;
- monitoring instrumentation; and
- process instrumentation and controls.

Process Facility

The OGS process equipment is housed in a reinforced-concrete structure to provide adequate shielding. Charcoal adsorbers are installed in a temperature monitored and controlled vault. The facility is located in the turbine building to minimize piping.

Power cycle condensate is used as the coolant for the offgas condensers. In this capacity, the temperature of condensate supplied to the offgas condenser should not exceed the values shown in Table 11.3-1 during periods of normal operation and startup (main condenser evacuation) operation. The pressure of condensate supplied to the offgas condenser should not exceed the design pressure of the condenser, and power cycle condensate isolation valves should be normally open to both recombiner condensers.

The gaseous waste stream is then cooled in the cooler condenser. Chilled water is provided at the temperature shown in Table 11.3-1. The cooler condenser is located immediately above the offgas condenser and is designed to allow the condensed moisture from the gaseous waste stream to drain back into the offgas condenser, from which it is sent to the main turbine condenser.

The gaseous waste stream is heated to the value shown in Table 11.3-1 by ambient heating in the charcoal vault.

Chapter 12 provides the radioactivity inventories of the major offgas system components during normal plant operation. The radiation shielding design provides adequate protection of instrumentation and plant personnel required to monitor and operate the system.

Releases

The significant gaseous wastes discharged to the OGS during normal plant operation are radiolytic hydrogen and oxygen, power cycle injected gasses and air in-leakage, and radioactive isotopes of krypton, xenon, nitrogen, and oxygen. The radiation dose from gaseous discharge is primarily external rather than ingestion or inhalation. When releasing gases from the plant, the plume or cloud is the source of radiation to the ground. The maximum radiation corresponds to the zone of maximum ground concentration. This, in turn, is a function of wind velocity and direction, the presence of building obstructions in the wake and other meteorological conditions in the area. From the foregoing considerations, a maximum release rate from the plant stack or vent can be established such that the maximum radiation dose to any area in the environs is not exceeded.

Radioactive particles are present as a result of radioactive decay from the noble gas parents. These particulates are removed from the offgas stream by the condensation and adsorption equipment. Therefore, effectively no radioactive particulates are released from the OGS to the plant stack.

Radioiodines (notably I^{131}) may be present in significant quantities in the reactor steam and to some extent carried over through the condensation stages of the OGS. Removal of iodine takes place in the passage of process gas through the activated charcoal adsorbers, so that essentially no iodine is released from the OGS to the plant stack.

The criterion for release of gaseous wastes to the atmosphere, excluding accident sequences, is that maximum external radiation dosage to the environment be maintained below the maximum dose objectives of Appendix I to 10 CFR 50 in terms of actual doses to actual off-site persons. An instantaneous release rate, established by 10 CFR 20, of several times the annual average permissible release rate limit is permitted as long as the annual average is not exceeded. Every reasonable effort has been made to keep radiation exposures and release of radioactive materials "as low as reasonably achievable" (ALARA). The OGS discharge is routed to the plant stack.

11.3.2.1 Process Design

Primary design features are shown on the simplified offgas diagram (Figure 11.3-1).

The steam jet air ejectors (SJAE) are described in DCD Subsection 10.4.2

Preheating

Recombiner preheaters preheat gases to provide for efficient catalytic recombiner operation and to ensure the absence of liquid water that suppresses the activity of the recombiner catalyst. Maximum preheater temperature does not exceed the value shown in Table 11.3-1 should gas flow be reduced or stopped. This is accomplished by using extraction steam as shown in Figure 10.1-2 - Rated Heat Balance. During startup, steam at this pressure, is available before the process offgas is routed through the preheater section to the recombiner catalyst section. Electrical preheaters are not exposed directly to the offgas.. Each preheater section connects to an independent final stage air ejector to permit separate steam heating of both recombiners during startup or drying one recombiner while the other is in operation. For reliability, preheater steam is nuclear steam. The preheater is sized to handle a dilution steam load of 115% of rated flow in addition to allowing for 5% plugged tubes.

Hydrogen/Oxygen Recombination

Minimum performance criteria for the catalytic recombiners are as follows:

- In normal full power operation the hydrogen in the recombiner effluent does not exceed 0.1% by volume on a moisture-free basis, at the defined minimum air flow shown in Table 11.3-1.
- During startup or other reduced power operations (between 1 and 50% of reactor rated power), the hydrogen in the recombiner effluent does not exceed 1.0% by volume on a moisture free basis at the defined minimum air flow.
- An intentional air bleed equal to minimum air flow is introduced into the system upstream of the operating recombiner when the turbine condenser air in-leakage falls below the defined minimum air flow. The out-of-service recombiner catalyst is heated to the value shown in Table 11.3-1 by dilution steam injection and preheat steam before admitting process gas (containing hydrogen) to the recombiner. Three temperature sensing elements are provided in each catalyst bed and are located to measure the temperature profile from inlet to outlet.

Condensing

The offgas condensers cool the recombiner effluent gas to the maximum temperatures for normal operation and startup operation shown in Table 11.3-1. The condenser includes baffles to reduce moisture entrainment in the offgas. The unit is sized to handle a dilution steam load of 115% of rated flow, in addition to allowing for 5% plugged tubes. The drain line is capable of draining the entire process condensate, including the 15% excess plus 2.5 l/s (40 gpm), from the unit at both startup and normal operating conditions, taking into account the possibility of condensate flashing in the return line to the main condenser. The drain line also incorporates a flow element so that higher flows caused by tube leakage can be easily identified, and a passive loop seal with a block valve operable from the main control room. A gas sample tap is provided downstream of and near the offgas condensers to permit gas sampling.

The gaseous waste stream is then cooled in the cooler condenser. The cooler condenser is designed to remove any condensed moisture by draining it to the offgas condenser.

Adsorption

The activated charcoal uses “arbitrary” adsorption coefficient Karb values for krypton and xenon. Separate Karb laboratory determinations of krypton and xenon are made for each manufacturer's lot unless the manufacturer can supply proof convincing to the purchaser that other lots of the same production run immediately adjacent to the lot tested are equivalent to the lot tested with respect to krypton and xenon adsorption. Other adsorption tests (e.g., dynamic coefficients) may be acceptable, provided their equivalence to Karb tests for this purpose can be demonstrated. Charcoal particle size, moisture content and minimum charcoal ignition temperature in air are shown in Table 11.3-1.

Properties of activated charcoal used in the adsorber vessels are an optimization of the following:

- high adsorption for krypton and xenon;
- high physical stability;
- high surface area;
- low pressure drop;
- low moisture absorption;
- high ignition temperature; and
- dust-free structure.

The Kr and Xe holdup time is closely approximated by the following equation:

$$T = \frac{K_d M}{V} \tag{11.3-1}$$

where

T	=	holdup time of a given gas
K_d	=	dynamic adsorption coefficient for the given gas
M	=	weight of charcoal
V	=	flow rate of the carrier gas

in consistent units.

Dynamic adsorption coefficient values for xenon and krypton were reported by Browning (Reference 11.3-7). GE Nuclear Energy has performed pilot plant tests at the Vallecitos Laboratory and the results were reported at the 12th AEC Air Cleaning Conference (Reference 11.3-8).

Noble Gas Mixture

The fission product noble gas composition used as the nominal design basis is defined in Section 11.1. During normal operation with no fuel leaks, release rate of noble gases (after 30-minute decay) may occur because of minute quantities of uranium contamination. The system is also capable of safe mechanical operation at release rates of up to the value identified in the Technical Specifications (refer to Subsection 16.3.7.2).

Air Supply

Carrier gas is the air leakage from the main condenser after the radiolytic hydrogen and oxygen are removed by the recombiner. The air in-leakage design basis is conservatively assumed to be the total value shown in Table 11.3-1.

An air bleed supply is provided for dilution of residual hydrogen at air in-leakages below the minimum value shown in Table 11.3-1, for valve stem sealing, for recombiner startup, for blocking during maintenance, for instrument operation, for providing an air flow through the standby recombiner when processing offgas, and for purging gas mixtures from process and instrument lines prior to maintenance. These normal air purge flow rates are not used while the system processes reactor offgas. The air is supplied from a compressor that does not use oil for lubrication of the compressor cylinder, as oil compromises the performance of the catalytic recombiners and charcoal adsorbers. During both startup and normal operation, air is bled to the standby recombiner train just downstream of the final SJAE suction valve for train purging after switchover. Flow indicators are provided on all air bleed lines to assure that proper air flow is being delivered to the process line or equipment. The air supply is protected from back flow of process gas by two check valves in series or by a check valve and a pressure control valve in series.

Range-ability

The process can accommodate reactor operation from 0 to 100% of full power. In normal operation, radiolytic gas production varies linearly with thermal power. The process can accommodate the airflow range shown in Table 11.3-1 for the full range of reactor power operation.

In addition, the process can mechanically accommodate a startup high airflow as shown on the process data sheet upon initiation of the steam jet air ejectors. This startup airflow results from evacuation of the turbine condensing equipment while the reactor is in the range of about 3% to 7% of rated power.

Redundancy

All active equipment (e.g., recombiners, and valves) whose operation is necessary to maintain operability of the OGS is redundant. Passive equipment (e.g., charcoal adsorber) is not redundant. Instrumentation that performs an information function and is backed up by design considerations or other instrumentation is not redundant. Instrumentation used to record hydrogen concentration or activity release (e.g., flow measurement and hydrogen analyzers) is redundant.

Design provisions are incorporated which preclude the uncontrolled release of radioactivity to the environment as a result of any single equipment failure short of the equipment failure accident described in Subsection 11.3.7. An analysis of single equipment piece malfunctions is provided in Table 11.3-3.

Design precautions taken to prevent uncontrolled releases of activity include the following:

- The system design minimizes ignition sources so that a hydrogen detonation is highly unlikely even in the event of a recombiner failure.
- The system pressure boundary is detonation-resistant in addition to the measure taken to avoid a possible detonation.
- All discharge paths to the environment are monitored. The normal effluent path is monitored by the Process Radiation Monitoring System and the equipment areas are monitored by the Area Radiation Monitoring System.
- Dilution steam flow to the steam jet air ejector is monitored and alarmed, and the valving is required to be such that loss of dilution steam cannot occur without coincident closure of the process gas suction valve(s) so that the process gas is sufficiently diluted if it is flowing at all.

Charcoal Adsorber Bypass

A piping and valving arrangement is provided, which allows isolation and bypass of the charcoal adsorber vessel most likely to catch fire or become wetted with water, while continuing to process the offgas flow through the remaining adsorber vessels. A nitrogen purge can be injected upstream of the vault entrance so that further combustion is prevented and the charcoal is cooled below its ignition temperature. Capability is provided to employ all or a portion of the charcoal adsorber vessels to treat the offgas flow during normal or off-standard process operating conditions. Capability is also provided to completely bypass all charcoal adsorber vessels during plant startup and/or when fuel performance allows.

The main purpose of this bypass is to protect the charcoal during preoperational and startup testing when gas activity is zero or very low and when moisture is most likely to enter the charcoal beds. The bypass valve arrangement is such that no single valve failure or valve misoperation would allow total charcoal bypass. The bypass mode of charcoal operation is not normal for power operation. However, it may be used if the resulting activity release is acceptable.

Valves

All valves with operators located on the gas process stream are operable from the main control room. Where radiation levels permit, valves handling process fluids are installed in service areas where maintenance can be performed if needed during operation.

Nitrogen and Air Purge

A nitrogen purge and air supply line is connected to the offgas process just upstream of the first in-line charcoal adsorber vessel (guard bed). This arrangement is to allow the vessel to be nitrogen purged after a possible fire is detected or dried with heated air if the charcoal is wetted, while the offgas flow is bypassed around it and through the remaining charcoal vessels. Another nitrogen purge line is also provided just upstream of the remaining charcoal adsorber vessels that allow them to be purged, if required, without interrupting the processing of offgas through the guard bed. The isolation valves in the nitrogen and air purge lines and the connection for the gas supply are accessible from outside the charcoal vault.

11.3.2.2 Component Design

For portions of the system that may contain an explosive mixture, the design provides for ignition sources to be minimized and the system to be able to sustain an explosion without loss of integrity.

Calculation methods for translation of detonation pressures into wall thickness are summarized in the ANSI-55.4 (Reference 11.3-6). Equipment are designed and constructed in accordance with the requirements of Table 11.3-2.

Materials

Per Regulatory Guide 1.143, Regulatory Position 1.1.2, materials for pressure-retaining components of process systems[1] are selected from those covered by the material specifications listed in Section II, Part A of the ASME Boiler and Pressure Vessel Code, except that malleable, wrought or cast-iron materials, and plastic pipe are not allowed in this application. The components satisfy all of the mandatory requirements of the material specifications with regard to manufacture, examination, repair, testing, identification, and certification.

Pressure Relief

Adequate pressure relief is provided at all locations where it is possible to isolate a portion of the system containing a potential heat source that could cause excessive pressure. Adequate pressure relief is also provided downstream of pressure reducing valves to protect equipment from overpressure.

Equipment Room Ventilation Control

The equipment rooms are under positive ventilation control. The equipment in the equipment rooms is qualified for the environmental conditions it is expected to see..

Differential pressure between general areas and equipment cells is sufficient to maintain a flow of air from clean areas into potentially contaminated areas. In addition, the TBHV is capable of removing sufficient heat from the process piping, equipment, motors, and instrumentation so as to maintain the environmental temperatures as established. All equipment cell and charcoal vault ventilation air is discharged without passing through occupied areas to the Turbine Building compartment exhaust system and the plant vent stack, where effluent radiation monitoring is performed.

Leakage

The leakage criteria apply from the steam jet air ejector through the OGS, including all process equipment and piping in between as shown on Figure 11.3-1. Leakage from the process through purge or tap lines to external atmospheric pressure is sufficiently low so it is undetectable by "soap bubble" test. This requirement does not apply to in-line process valves.

Instrument panels (e.g., hydrogen analyzers) connected to process gas are enclosed, the enclosure maintained under a negative pressure, and vented to an equipment vault or to building ventilation. To reduce instrument line leakage, welded rather than threaded connections are used wherever possible.

---

1 "Process System" refers to that portion of the OGS that normally processes SJAE Offgas.

Vents and Drains

Offgas System drains, depending on source, are routed to either the condenser hotwell or to the radwaste system. All piping is provided with high point vents and low point drains to permit system drainage following the hydrostatic test. A water drain is provided on the process lines just upstream of the charcoal tanks. The process line to and from the charcoal adsorbers is sloped so that there are no intervening low spots to act as water traps.

Valves

No valves controlling the flow of process gas are located in the charcoal adsorber vault. For all valves exposed to process offgas, valve seats are designed to avoid sparks.

All valves exposed to process gas have bellows stem seals, double stem seals or equivalent.

Recombiners

The recombiners are mounted with the gas inlet at the bottom. The inlet piping has sufficient drains and moisture separators to prevent liquid water from entering the recombiner vessel during startup. The recombiners are catalytic type with non-dusting catalyst supported on a metallic base. The catalyst is replaceable without requiring replacement or removal of the external pressure vessel.

Each recombiner is part of an integrated preheater-recombiner-condenser pressure vessel assembly. The preheater section uses nuclear quality steam to heat the offgas process stream gases to at least the minimum values shown in Table 11.3-1 before it reaches the catalyst in the recombiner section. The recombined hydrogen and oxygen, in the form of super-heated steam, which leaves the recombiner section, is then condensed (by power cycle condensate) to liquid water in the condenser section of the assembly, while the noncondensable gases are cooled to temperatures below the maximum value shown in Table 11.3-1. The condensed water in the condenser section is drained to a loop seal that is connected to the main condenser hotwell. Condensed preheater section steam is drained to the above loop seal that is connected to the hotwell.

No flow paths exist whereby unrecombined offgas can bypass the recombiners.

Charcoal Adsorber Vessels

The charcoal adsorber vessels are to be cylindrical tanks installed vertically.

Channeling in the charcoal adsorbers is prevented by supplying an effective flow distributor on the inlet and by a high bed-to-particle diameter ratio. Temperature elements are installed along the charcoal adsorber vessels in sufficient quantity to monitor the temperature profile along the flow path during operation.

Charcoal Adsorber Vault

The temperature within the charcoal adsorber vault is maintained and controlled by appropriate connection(s) to the Turbine Building HVAC System. The decay heat is sufficiently small that, even in the no-flow condition, there is no significant loss of adsorbed noble gases because of temperature rise in the adsorbers.

The charcoal adsorber vault itself is designed for the temperature range shown in Table 11.3-1 because it may be necessary to heat a vessel or the vault to the maximum temperature (by the use of portable heaters) to facilitate drying the charcoal. A smoke detector is installed in the exhaust ventilation duct from the charcoal adsorber vault to detect and provide alarm to the operator as a charcoal fire within the vessel(s) usually results in the burning of the exterior paint surface.

Construction of Process Systems

Pressure-retaining components of process systems employ welded construction to the maximum practicable extent. Process piping systems include the first root valve on sample and instrument lines. Process, sample and instrument line construction parameters are provided in Table 11.3-4.

Moisture Separator

A moisture separator is incorporated into the cooler-condenser heat exchanger.

Maintenance Access

The system equipment is generally not accessible for maintenance during system operation. All equipment is accessible during the plant outages. The following are exceptions:

- The redundant offgas recombiner trains are located in separate rooms to allow maintenance access to the standby train when processing offgas in the operable train.
- Control valving and hydrogen analyzers are accessible for maintenance during the out-of-services portion of their cycle.
- Charcoal vault air conditioning and ventilation equipment are accessible for maintenance during plant operation.

The OGS is designed, constructed, and tested to be as leak tight as practicable.

Design features which reduce or ease required maintenance or which reduce personnel exposure during maintenance include the following:

- redundant components for all active, in-process equipment pieces located in separate shielded cells;
- no rotating equipment in the radioactive process stream;
- block valves with air bleed pressurization for maintenance which may be required during plant operation; and
- shielding of nonradioactive auxiliary subsystems from the radioactive process stream.

Design features that reduce leakage and releases of radioactive material include the following:

- extremely stringent leak rate requirements placed upon all equipment, piping and instruments and enforced by requiring as-installed helium leak tests of the entire process system;
- use of welded joints wherever practicable;
- specification of valve types with extremely low leak rate characteristics (i.e., bellows seal, double stem seal, or equal);
- routing of most drains through loop seals to the main condenser; and

- specification of stringent seat-leak characteristics for valves and lines discharging to the environment through other systems.

11.3.2.3 Seismic Design

Offgas System equipment and piping are classified Seismic Category NS.

11.3.3 Ventilation System

Radioactive gases are present in the power plant buildings as a result of process leakage and steam discharges. The process leakage is the source of the radioactive gases in the air discharged through the ventilation system. The design of the ventilation system is described in Section 9.4. The radiation activity levels from the ventilation systems are treated in Section 12.2. The ventilation flow rates are shown in Section 9.4.

11.3.4 Radioactive Releases

Refer to Subsection 12.2 for radioactive release information from the OGS.

11.3.5 Testing and Inspection Requirements

Because the gaseous radioactive waste system has no safety function, no inservice inspection of the components is required.

Preoperational and startup testing, which includes hydrostatic testing of system components and piping; helium leak testing; and verification of air ejector pressure and flow, preheater operation (recombiner inlet temperature), catalyst temperature, and offgas condenser operation; is accomplished as described within Section 14.2.

During normal operation, the hydrogen analyzers, process components, and monitoring instrument channels are periodically tested and calibrated to ensure that the explosive gas mixture is below the flammability limit and projected doses from gaseous effluent releases are kept as low as reasonably achievable and below regulatory limits.

11.3.6 Instrumentation Requirements

Control and monitoring of the OGS process equipment is performed both locally and remotely from the main control room. Generally, system control is from the main control room. Instrument components are installed wherever possible in accessible areas to facilitate operation and maintenance. Only instrument sensing elements are permitted behind shield walls.

The temperature of the gaseous waste stream is measured in the preheater and at various locations in the recombiner to assure that recombination is occurring. The gaseous waste stream temperature is also measured after both the offgas condenser and the cooler condenser to assure the stream is cooled sufficiently to remove undesired moisture. All of these temperatures are alarmed in the main control room.

The flow rate of the offgases is continuously monitored. This flow rate, in conjunction with activity concentrations , as measured by the monitor downstream of the recombiners and the monitor downstream of the charcoal adsorbers, permits monitoring fission gases from the reactor, calculation of offgas discharge to the vent , and calculation of the charcoal adsorber system performance.

11.3.7 Radioactive OffGas System Leak or Failure

11.3.7.1 Basis and Assumptions

The radiological consequences for an Offgas System accident as specified in Standard Review Plan 11.3, Branch Technical Position ESTB 11-5 are presented. The branch technical position assumptions were used except as detailed below to evaluate this accident. The accident parameters are shown in Table 11.3-5. The results are presented in Tables 11.3-6 and 11.3-7 and show the ESBWR design to be compliant with the requirements of the Branch Technical Position.

The system is designed to be both detonation and seismic resistant and meets all criteria of Regulatory Guide 1.143. As such, the failure of a single active component leading to a direct release of radioactive gases to the environment is highly unlikely. Therefore, inadvertent operator action with bypass of the delay charcoal beds is analyzed for compliance to ESTB 11-5. A top-level diagram of the ESBWR Offgas System can be found in Figure 11.3-1 that shows the ESBWR charcoal beds consist of nine charcoal tanks. The first, or guard, tank contains charcoal followed by a flow split into four lines, each line of which leads through two massive tanks, each containing charcoal. Bypass valves exist to direct flow around the (1) guard tank, (2) four series of follow-on tanks, or (3) all tanks. To bypass either pathway (1) or (2) above requires the operator to enter a computer command with a required permissive. To bypass all tanks [pathway (3)] requires the operator to key in the command with two separate permissives. Because pathway (3) would require both inadvertent operation upon the operator (keying in the wrong command) plus getting two specific permissives for three incorrect decisions, it is not assumed that inadvertent entry into pathway (3) is likely to occur. Redundant upon human decision-making and downstream of the charcoal beds shown on Figure 11.3-1 are a series of two redundant radiation monitoring instruments and an air-operated isolation valve. Upon receiving a Hi signal, the system alarms the control room, where a Hi-Hi signal automatically initiates a "treat" mode, causing flow to process through the charcoal tanks, and override switch settings. Therefore, bypass of the charcoal beds during periods with significant radioactive flow through the Offgas System are limited and/or automatically terminated by actuation of the downstream sensors.

To evaluate the potential radiological consequences of an inadvertent bypass of the charcoal beds, it was assumed that operator error or computer error has led to the bypass of the eight follow-on beds in addition to the failure of the automated air-operated downstream isolation valve. It is also assumed that during this period, the plant is running at, and continues to run at, the maximum permissible offgas release rate contained in the Technical Specifications (refer to Subsection 16.3.7.2). The analysis is based upon the assumption of 100 μCi/sec/MWt as stipulated in Standard Review Plan 11.3 evaluated to a decay time of 30 minutes from the vessel exit nozzle. Even with the failure of the downstream isolation valve, it is not anticipated or assumed that the isolation instrumentation would fail, but would instead alarm the control room with a high radiation alarm, causing the operator to manually isolate the Offgas System (i.e., close suction valves) within 30 minutes of the alarm.

Therefore, this analysis differs from the branch technical position on the following points:

- There is no motive force to remove any significant inventory from the eight follow-on charcoal tanks while in bypass and, therefore, no activity from these tanks is included in the final release calculations.
- With redundant instrumentation, it is expected that operator intervention to either shut off the bypass or isolate the Offgas System is predicted to occur within 30 minutes. Therefore, the total flow from the system is evaluated for 30 minutes and not the 2-hour period stipulated in Branch Technical Position ESTB 11-5.

11.3.7.2 Results

The DBA evaluation assumptions are given in Table 11.3-5, the isotopic flows and releases in Table 11.3-6, and the meteorology and dose results in Table 11.3-7.

The dose results are given in Table 11.3-8 and are within the limiting 25 mSv (2.5 Rem) whole body dose for an infrequent event or the 5 mSv (0.5 Rem) frequent event limitation of Branch Technical Position ESTB 11-5.

11.3.8 COL Information

11.3.8.1 Offgas System Data

Offgas System design parameters, major equipment items as well as other system data, as shown in tables 11.3-2 and 11.3-4, are to be defined by the COL applicant.

11.3.9 References

11.3-1 Code of Federal Regulations 10 CFR 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions to Meet the 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water Cooled Nuclear Power Reactors."

11.3-2 Code of Federal Regulations 10 CFR 20, "Standards for Protection Against Radiation."

11.3-3 Nuclear Regulatory Commission (NRC), Regulatory Guide 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants."

11.3-4 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII - Division 1.

11.3-5 American Institute of Steel Construction (AISC), Manual of Steel Construction

11.3-6 American National Standards Institute, "Gaseous Radioactive Waste Processing Systems for Light Water Reactor Plants," ANSI/ANS-55.4.

11.3-7 W.E. Browning, et al., "Removal of Fission Product Gases from Reactor Offgas Streams by Absorption," June 11, 1959, Oak Ridge National Laboratory (ORNL) CF59-6-47.

11.3-8 D.P. Seigwarth, "Measurement of Dynamic Absorption Coefficients for Noble Gases on Activated Carbon," Proceedings of the12th AEC Air Cleaning Conference.

11.3-9 Dwight Underhill, et al., "Design of Fission Gas Holdup Systems, Proceedings of the Eleventh AEC Air Cleaning Conference," 1970, p. 217.

11.3-10 General Electric Co., "Radiological Accident Evaluation - The CONAC03 Code," NEDO-21143-1, December 1981.

Table 11.3-1

Offgas System Design Parameters*

Design Parameter	Design Value
Design Basis annual average noble radiogas release rate	3700 MBq/s (100, 000 µCi/s)
Assumed air in-leakage	51 m^3/h (30- scfm)
Xenon delay	60- day
Maximum gaseous waste stream temperature	67 °C (153 °F)
Charcoal temperature (approximate)	35 °C (100 °F)
Maximum condensate temperature during normal operation	57°C (135 °F)
Maximum condensate temperature during startup	43 °C (109 °F)
Maximum cooler condenser temperature	18 °C (65 °F)
Chilled water temperature	-7°C (45°F)
Gaseous waste stream temperature	38 °C (100 °F)
Nominal recombiner preheater temperature	177 °C (351 °F)
Maximum recombiner preheater temperature	210 °C (410 °F)
Hydrogen/oxygen catalytic recombiner defined minimum air flow	0.17 m^3/min (6 scfm)
Out-of-service hydrogen/oxygen catalytic recombiner minimum temperature	121 °C (250°F)
Maximum recombiner effluent gas temperature during normal operation	67 °C (153 °F)
Maximum recombiner effluent gas temperature during startup	57 °C (135 °F)
Minimum activated charcoal ignition temperature	156 °C (313 °F)

* For additional information on radioactive releases, refer to Subsection 11.1 or 12.2.

Table 11.3-1

Offgas System Design Parameters*

Design Parameter	Design Value
Minimum air bleed supply rate	0.17 m^3/min (6 scfm)
Air bleed to standby recombiner train at startup and normal operation	0.17 m^3/min (6 scfm)
Air flow range	0.17 m^3/min (6 scfm) to 7 m^3/min (247 scfm)
Recombiner preheat minimum temperature	* °C (* °F)
Recombiner noncondensable gas maximum temperature	67.8 °C (154 °F)
Charcoal adsorber vault temperature range	29 °C (84 °F) to 40 °C (104 °F)
Charcoal particle size	8 – 16 mesh (USS) with less than 0.5% under 20 mesh
Charcoal moisture content	< 5% by weight
Major offgas activity maximum permissible concentration (MPC)	6.2E+6 Bq/cm^3

Table 11.3-2

Offgas System Major Equipment Items

Recombiner (Item D005, 2 required, contains preheater, catalyst, and condenser sections)**	
Carbon steel shell	
Design pressure:	2.44 MPa gauge (350 psig)
Design temperature:	232 °C(450 °F)
Code of construction:	ASME Section VIII, Division 1
Preheater Section	Shell and tube heat exchanger
Tubes:	stainless steel
Tube-side design pressure:	2.41 MPa gauge (350 psig)
Design temperature:	232 °C (450 °F)
Catalyst section	
Catalyst support:	stainless steel
Design temperature:	482 °C (900 °F)
Catalyst:	precious metal on metal base
Offgas condenser section	Shell and tube heat exchanger
Tubes:	stainless steel
Tube-side design pressure:	2.41 MPa gauge (350 psig)
Design temperature:	482 °C (900 °F)
Cooler Condenser (Item B010, 2 required)**	
Shell and tube heat exchanger, carbon steel vessel	
Shell-side design pressure:	2.41 MPa gauge (350 psig)
Shell-side design temperature:	0 to 121 °C (32 to 250 °F)
Tubes:	stainless steel
Tube-side design pressure:	0.69 MPa gauge (100 psig)
Tube-side design temperature:	0 to 65.6 °C (32 to 150 °F)
Code of construction:	TEMA Class C
Charcoal Adsorbers (Items D012A and D012B-J)	
Carbon steel vessels filled with activated charcoal	
Design pressure:	2.41 MPa gauge (350 psig)
Design temperature:	4.4 to 121 °C (40 to 250 °F)
Code of construction:	ASME Section VIII, Division 1

** Potential variation in parameters may be considered in COL phase (see subsection 11.3.8.1 for COL Information).

Table 11.3-3

Equipment Malfunction Analysis

Equipment Item	Malfunction	Result(s)	Design Precautions
Steam jet air ejectors	Low flow of motive high pressure steam	If the hydrogen and oxygen concentrations exceed 4 vol %, the recombiner's temperature rise is excessive.	Automatic system isolation on low steam flow.
		Inadequate steam flow causes overheating and may result in exceeding the design temperature of the recombiner vessel.	Steam flow to be held at constant maximum flow regardless of plant power level.
	Wear of steam supply nozzle of ejector	Increased steam flow to recombiner could reduce degree of recombination at low power levels. High discharge temperature from recombiner condenser could result because of inadequate condenser capacity.	Temperature alarms on preheater exit (catalyst inlet). Downstream H_2 analyzer alarms. High temperature alarms on exit from recombiner.
Recombiner preheater	Steam leak	Steam consumption would increase.	Spare recombiner train.
	Low-pressure steam supply	Recombiner performance could fall off at low-power level, and hydrogen content of recombiner gas discharge could increase eventually to a combustible mixture.	Low temperature alarms on preheater exit (catalyst inlet). Downstream H_2 analyzer alarm.
Recombiner catalyst	Catalyst gradually deactivates	Temperature profile changes through catalyst. Eventually excess H_2 would be detected by H_2 analyzer or by offgas flowmeter. Eventually the gas could become combustible.	Temperature probes in catalyst bed and H_2 analyzer provided. Spare recombiner train.
	Catalyst gets wet at start	H_2O_2 recombination fails. Eventually the gas downstream of the recombiner could become combustible.	Condensate drains, temperature probes in recombiner. Air bleed system at startup. Spare recombiner. Hydrogen analyzer.

Table 11.3-3

Equipment Malfunction Analysis

Equipment Item	Malfunction	Result(s)	Design Precautions
Recombiner condenser	Cooling water leak	The coolant (reactor condensate) would leak to the process gas (shell) side. This would be detected by drain flow increase. Moderate leakage would be of no concern from a process standpoint. (The process condensate drains to the hotwell.)	Drain high flow alarm. Redundant recombiner.
Cooler condenser	Corrosion of tubes	Water would leak into process (shell) side and be sent to main condenser hotwell.	Stainless-steel tubes specified. Conductivity cell in condenser drain.
Moisture separator in cooler condenser	Corrosion of wire mesh element	Increased moisture would be retained in process gas routed to charcoal over a long period.	Stainless steel mesh specified. Spare cooler condenser provided. Levels in pre-charcoal drain.
Charcoal adsorbers	Charcoal gets wet	Charcoal performance deteriorates gradually as moisture deposits. Holdup times for krypton and xenon would decrease, and plant emissions would increase. Provisions made for drying charcoal as required during annual outage.	High instrumented, mechanically simple gas dehumidification system.
System	Internal detonation	Release of radioactivity if pressure boundary fails	Main process equipment and piping are designed to contain a detonation.
		Internal damage to the recombiner and its heat exchanger	Redundant recombiner, damaged internals can be repaired.
		Damage to instrumentation sensors	Redundant, damaged sensors can be replaced.
System	Earthquake damage	Release of radioactivity	Dose consequences are within the design guidance of BTP ETSB 11-5.

Table 11.3-4

Construction of Process Systems

Component	Parameter	Value
Process lines	Diameter	≥50 mm (2-inch nominal)
Screwed connections, in which threads provide the only seal	Not used	Not applicable
Lines using screw-seal welding or mechanical joints	Diameter	≤ 20 mm (0.75-inch nominal)
Lines 20 mm (0.75-inch nominal) pipe size or greater, but less than 65 mm (2.5-inch nominal)	Weld type	Socket type welds
Lines 65 mm (2.5-inch nominal) pipe size and larger	Weld type	Butt joint type

Construction requirements could change in the COL phase (see 11.3.8.1 for COL information)

Table 11.3-5

Offgas System Failure Accident Parameters

I. Data and Assumptions Used to Estimate Source Terms	
a. Power Level	4,500 MWt
b. Offgas Release Rate	1.67E+4 MBq/s[1] (4.5E+5 μCi/s)
c. Charcoal Delay	
Kr	0.5 h
Xe	0.5 h
d. Duration of Release	0.5 h
e. Design Basis Rate	1.67E+4 MBq/s (4.5E+5 μCi/s)
II. Dispersion and Dose Data	
a. Meteorology	Table 11.3-7
b. Dose Methodology	Reference 11.3-10
c. Dose Conversion Assumptions	Reference 11.3-10, RG 1.109
d. Activity Releases	Table 11.3-6
e. Dose Evaluations	Table 11.3-7

[1]Isotopic rates refer to a 30-minute decay time.

Table 11.3-6

Isotopic Source and Releases to the Environment

A. Isotopic Flow Rates for Design Basis[*]						
	T=0		T=2 min		T=30 min	
Isotope	MBq/s	Ci/s	MBq/s	Ci/s	MBq/s	Ci/s
Kr-83m	1.30E+2	3.53E-3	1.29E+2	3.48E-3	1.08E+2	2.93E-3
Kr-85m	2.22E+2	5.99E-3	2.21E+2	5.96E-3	2.05E+2	5.54E-3
Kr-85	8.88E-1	2.40E-5	8.88E-1	2.40E-5	8.88E-1	2.40E-5
Kr-87	7.30E+2	1.97E-2	7.16E+2	1.94E-2	5.55E+2	1.50E-2
Kr-88	7.33E+2	1.98E-2	7.27E+2	1.97E-2	6.48E+2	1.75E-2
Kr-89	4.43E+3	1.20E-1	2.87E+3	7.75E-2	6.44E+0	1.74E-4
Total						4.12E-2
Xe-131m	7.30E-1	1.97E-5	7.30E-1	1.97E-5	7.29E-1	1.97E-5
Xe-133m	1.09E+1	2.94E-4	1.09E+1	2.94E-4	1.08E+1	2.92E-4
Xe-133	3.10E+2	8.38E-3	3.10E+2	8.38E-3	3.09E+2	8.36E-3
Xe-135m	9.42E+2	2.55E-2	8.63E+2	2.33E-2	2.50E+2	6.77E-3
Xe-135	8.42E+2	2.27E-2	8.39E+2	2.27E-2	8.10E+2	2.19E-2
Xe-137	5.89E+3	1.59E-1	4.10E+3	1.11E-1	2.56E+1	6.93E-4
Xe-138	3.33E+3	8.99E-2	3.02E+3	8.15E-2	7.70E+2	2.08E-2
Total						5.88E-2
Kr+Xe						1.00E-1

[*] Only the major isotopic constituents are identified.

Table 11.3-6
Isotopic Source and Releases to the Environment (Continued)

B. Environmental Releases from Guard Bed*				
	Charcoal Release Rate		Charcoal Releases	
Isotope	MBq/s	Ci/s	MBq	Ci
Kr-83m	4.88E+2	1.32E-2	8.78E+5	2.37E+1
Kr-85m	9.22E+2	2.49E-2	1.66E+6	4.49E+1
Kr-85	4.00E 0	1.08E-4	7.19E+3	1.94E-1
Kr-87	2.50E+3	6.75E-2	4.80E+6	1.21E+2
Kr-88	2.91E+3	7.87E-2	5.24E+6	1.42E+2
Kr-89	2.90E+1	7.83E-4	5.21E+4	1.41E 0
Total	6.85E+3	1.85E-1	1.23E+7	3.33E+2
Xe-131m	3.28E 0	8.86E-5	5.90E+3	1.60E-1
Xe-133m	4.86E+1	1.31E-3	8.75E+4	2.37E 0
Xe-133	1.39E+3	3.76E-2	2.51E+6	6.77E 0
Xe-135m	1.13E+3	3.05E-2	2.03E+6	5.48E+1
Xe-135	3.65E+3	9.85E-2	6.56E+6	1.77E+2
Xe-137	1.15E+2	3.12E-3	2.08E+5	5.61E 0
Xe-138	3.46E+3	9.36E-2	6.23E+6	1.68E+2
Total	9.80E+3	2.65E-1	1.76E+7	4.77E+2
Kr+Xe	1.67E+4	4.50E-1	3.00E+7	8.10E+2

* Only the major isotopic constituents are identified.

Table 11.3-7

Offgas System Failure Meteorology and Dose Results

Meteorology	Whole Body Dose
1.0 E-3 s/m^3	1.55 E-3 Sv

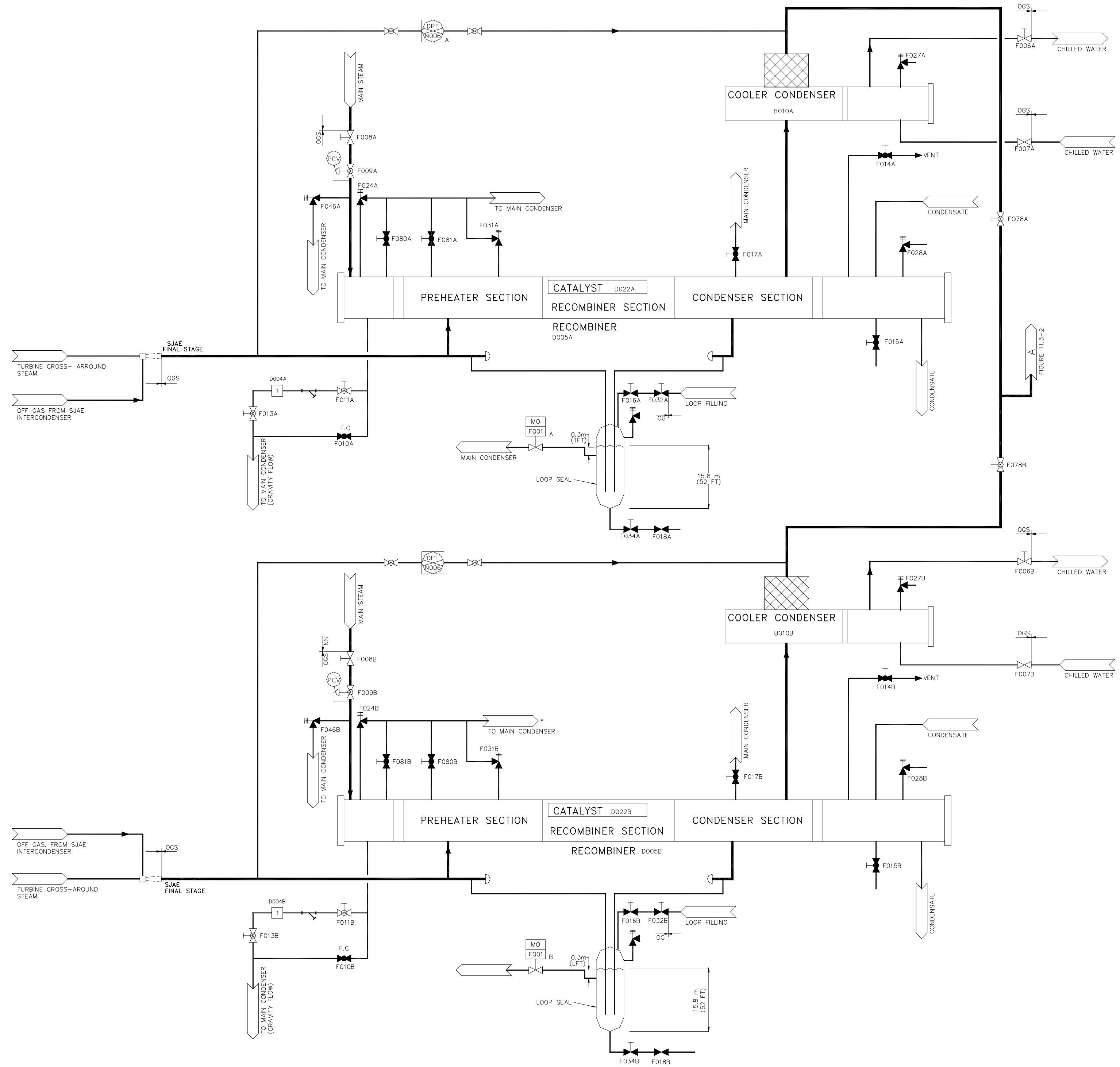


Figure 11.3-1. Offgas System Sh 1 of 2

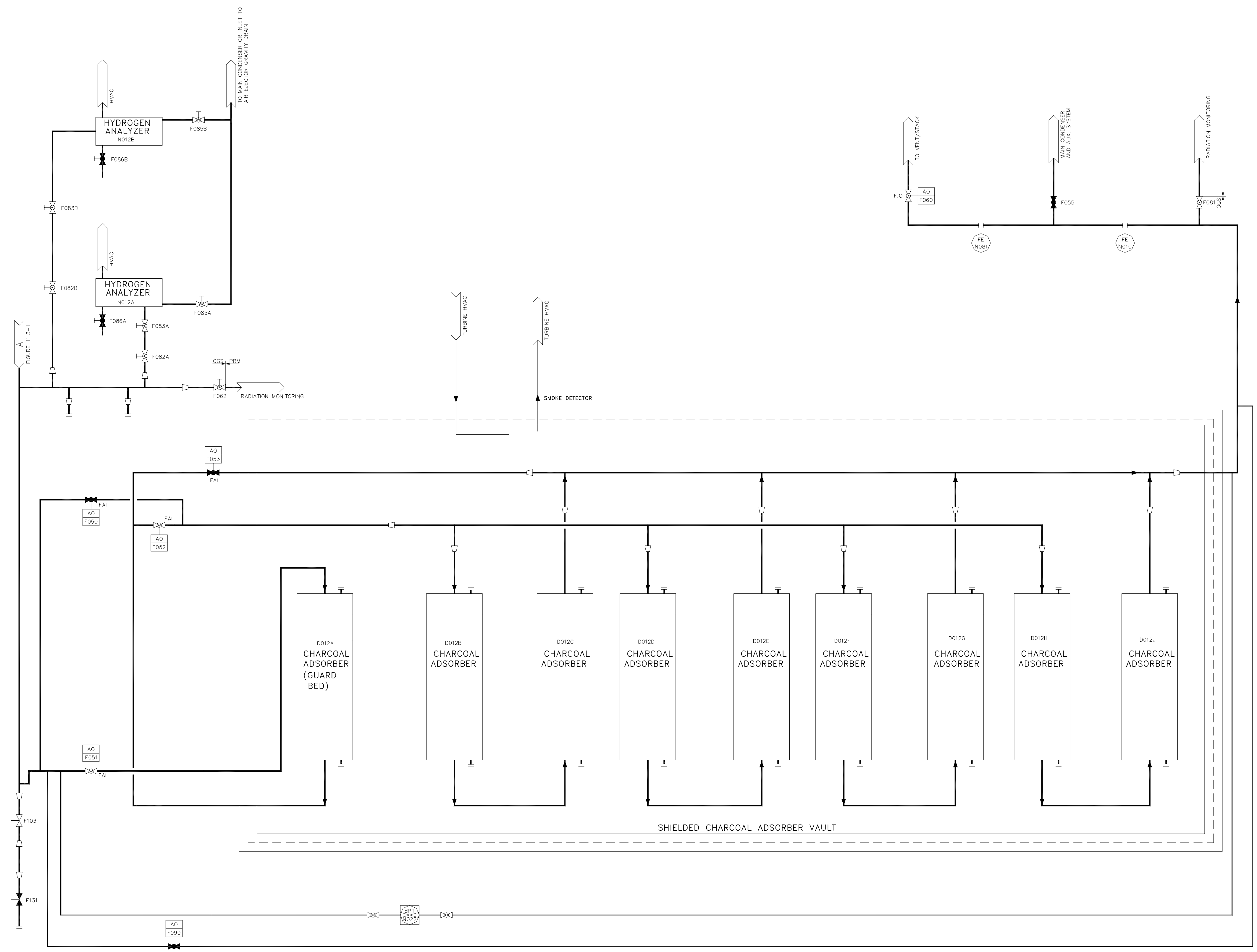


Figure 11.3-1. Offgas System Sh 2 of 2

11.4 SOLID WASTE MANAGEMENT SYSTEM

The Solid Waste Management System (SWMS) is designed to control, collect, handle, process, package, and temporarily store wet and dry solid radioactive waste prior to shipment. This waste is generated as a result of normal operation and anticipated operational occurrences.

The SWMS is located in the radwaste building. It consists of the following four subsystems:

- wet solid waste collection subsystem;
- mobile wet solid waste processing subsystem;
- dry solid waste accumulation and conditioning subsystem;
- container storage subsystem;

The SWMS Process Diagram depicting all four subsystems is provided in Figure 11.4-1. A conceptual radwaste building general arrangement drawing is provided in Figures 1.2-21 thru 1.2-25. The SWMS component capacities are provided in Table 11.4-1. The estimated annual shipped waste volumes generated from the SWMS subsystems are provided in Table 11.4-2. The SWMS has the capability to process wastes at rates higher than shown in Table 11.4-2. The isotopic inventory of the as-shipped waste is provided by waste type in Chapter 12.

Process and effluent radiological monitoring systems are described in Section 11.5.

11.4.1 Design Bases

Safety Design Bases

The SWMS has no safety-related function.

Power Generation Design Bases

The SWMS is designed to provide collection, processing, packaging, and storage of bead resin, filter backwash, and dry solid waste resulting from normal operations.

- The SWMS is designed to meet the requirements of Regulatory Guide 1.143.
- The SWMS is designed to keep the exposure to plant personnel "as low as reasonably achievable" (ALARA) during normal operation and plant maintenance, in accordance with Regulatory Guide 8.8.
- The SWMS is designed to package solid waste in DOT-approved containers for off-site shipment and burial.
- The SWMS is designed to prevent the release of significant quantities of radioactive materials to the environment so as to keep the overall exposure to the public well within 10 CFR 20 limits and in accordance with the limits specified in 10 CFR 50.
- The SWMS is designed to package the wet and dry types of radioactive solid waste for off-site shipment and burial, in accordance with the requirements of applicable NRC and DOT regulations, including 10 CFR 61, 10 CFR 71 and 49 CFR 170 through 178. This results in radiation exposures to individuals and the general population well within the limits of 10 CFR 20 and 10 CFR 50.

- The seismic and quality group classification and corresponding codes and standards that apply to the design of the SWMS components and piping, and the structures housing the SWMS are discussed in Section 3.2.
- On-site storage space for 6-month's volume of packaged waste is provided in the radwaste building.
- All atmospheric collection and storage tanks are provided with an overflow connection at least the size of the largest inlet connection. The overflow is connected below the tank vent and above the high level alarm setpoint. Each tank room is designed to contain the maximum liquid inventory in the event that the tank ruptures.

Process and effluent radiological monitoring systems are described in Section 11.5.

11.4.2 System Description

11.4.2.1 Summary Description

The SWMS controls, collects, handles, processes, packages, and temporarily stores solid waste generated by the plant prior to shipping the waste offsite. The SWMS processes the filter backwash sludges and bead resins generated by the Liquid Waste Management System (LWMS), Reactor Water Cleanup/Shutdown Cooling System (RWCU/SDC), Fuel and Auxiliary Pools Cooling System (FAPCS) and the Condensate Purification System. Contaminated solids such as high efficiency particulate air (HEPA) and cartridge filters, rags, plastic, paper, clothing, tools, and equipment are also disposed of in the SWMS.

The SWMS is capable of receiving, processing, dewatering the solid radioactive waste inputs for permanent off-site disposal. There is no liquid plant discharge from the SWMS.

11.4.2.2 System Operation

The SWMS consists of four process subsystems:

Wet Solid Waste Collection Subsystem

The wet solid waste collection subsystem collects the spent bead resin slurry, filter and tank sludge slurry and concentrated waste into the one of the five tanks in accordance with the waste characteristics.

Spent bead resin sluiced from the RWCU, FAPCS, Condensate Purification System and LWMS are transferred to three spent resin tanks for radioactive decay and storage. Spent resin tanks are categorized as follows:

- High Activity Resin Holdup Tank for receiving RWCU and FAPCS spent bead resin,
- Low Activity Resin Holdup Tank for receiving LWMS spent bead resin,
- Condensate Resin Holdup Tank for receiving Condensate Purification System spent bead resin.

The capability exists to keep the higher activity resins, the lower activity resins and condensate resins in separate tanks. Excess water from a holdup tank is sent to the equipment drain collection tank or floor drain collection tank by a decant pump.

When sufficient bead resins have been collected in the high/low activity resin holdup tank, they are mixed via the high/low activity resin circulation pump and sent to the mobile wet solid waste processing subsystem via the high/low activity resin transfer pump. When sufficient bead resins have been collected in the condensate resin holdup tank, they are mixed via the condensate resin circulation pump and sent to the LWMS pre-treatment ion-exchanger for reuse or the mobile wet solid waste processing subsystem via the condensate resin transfer pump.

Two Low Activity Phase Separators receive suspended solid slurries from the Condensate Purification System, mobile filtration system of the LWMS and high integrity containers (HIC) effluent. The suspended solids are allowed to settle and the residual water is transferred by the low activity decant pump to the equipment drain collection tanks or floor drain collection tanks for further processing. When sufficient sludges have been collected in the tank, the sludges are mixed by the low activity resin circulation pump and sent to the mobile wet solid waste processing subsystem by the low activity resin transfer pump.

During transfer operations of the spent bead resins and the sludges, the suspended solids are kept suspended by a circulation pump to prevent them from agglomerating and possibly clogging lines.

One Concentrated Waste Tank receives concentrated waste from the mobile reverse osmosis system of the LWMS. When sufficient concentrated waste has been collected in the tank, the concentrated waste is sent to the mobile wet waste processing subsystem by a mixing/transfer pump.

Mobile Wet Solid Waste Processing Subsystem

The mobile wet solid waste processing subsystem consists of a dewatering station for high activity spent resin, a dewatering station for low activity spent resin and sludge and a dewatering station (or dryer) for concentrated waste. An empty HIC is lifted off of a transport trailer and placed in each empty dewatering station. The tractor/trailer may then be released. The HIC closure lid is removed and placed in a laydown area. Spent cartridge filters may be placed in the HIC at this point, if not shipped in separate containers.

Next, the fill head is positioned over the HIC using a crane. The fill head includes a closed circuit television camera for remote viewing of the fill operation. The HIC is then filled with each kind of wet solid waste. The capability to obtain samples during the fill operation is provided.

Excess water is removed from the HIC and sent by a resin pump to the high activity resin holdup tank or a low activity phase separator that is in the receiving mode by a resin pump. Sufficient water is removed to ensure there is very little or no free standing water left in the HIC. Drying of the HIC contents may also be performed with heated air.

The fill head is then removed and placed in a laydown area. The closure head is then placed on the HIC. The HIC is vented just prior to being shipped off-site for disposal to ensure that pressure is not building up. Radiation shielding is provided around the HIC stations.

The estimated annual shipped waste volumes from processing wet solid wastes are presented in Table 11.4-2.

Dry Solid Waste Accumulation and Conditioning Subsystem

Dry solid wastes consist of air filters, miscellaneous paper, rags, etc., from contaminated areas; contaminated clothing, tools, and equipment parts that cannot be effectively decontaminated; and solid laboratory wastes. The activity of much of this waste is low enough to permit handling by contact. These wastes are collected in containers located in appropriate areas throughout the plant, as dictated by the volume of wastes generated during operation and maintenance. The filled containers are sealed and moved to controlled-access enclosed areas for temporary storage.

Most dry waste is expected to be sufficiently low in activity to permit temporary storage in unshielded, cordoned-off areas. Dry active waste will be sorted and packaged in a suitably sized container that meets DOT requirements for shipment to either an off-site processor or for ultimate disposal. The dry active waste is separated into three categories: non-contaminated wastes (clean), contaminated metal wastes, and the other wastes, i.e., clothing, plastics, HEPA filters, components, etc.

In some cases, large pieces of miscellaneous waste are packed into larger boxes. Because of its low activity, this waste can be stored until enough is accumulated to permit economical transportation to an off-site burial ground for final disposal.

The capability exists to bring a shipping container into the truck bay during periods of peak waste generation. Bagged dry active waste can be directly loaded into the shipping container for burial or processing in off-site facilities. A truck scale is provided to ensure optimum shipping/disposal weight of the shipping container.

Cartridge filters that are not placed in HICs are placed in suitability-sized containers meeting DOT requirements.

The estimated shipped waste volumes from processing dry active wastes are presented in Table 11.4-2.

Container Storage Subsystem

On-site storage space for 6-months volume of packaged waste is provided. Packaged waste includes HICs, shielded filter containers and 55-gallon (200-liter) drums as necessary.

11.4.2.3 Detailed System Component Description

The major components of the SWMS are as follows:

Pumps

Two types of pumps are utilized in the SWMS.

The SWMS process pumps are centrifugal pumps constructed of materials suitable for the intended service.

Air-operated, double-diaphragm type pumps are utilized in dewatering stations.

Tanks

Tanks are sized to accommodate a sufficient volume of waste sludges or bead resin to fill a HIC. The SWMS tanks are sized for normal plant waste volumes with sufficient excess capacity to accommodate equipment downtime and expected maximum volumes that may occur. The tanks are constructed of stainless steel to provide a low corrosion rate during normal operation. They are provided with mixing eductors and/or air spargers. The capability exists to sample all SWMS tanks. All SWMS tanks are vented through a filtration unit and the exhausted air is eventually discharged into the plant vent. The SWMS tanks are designed in accordance with ASME Section III, Class 3; API 620; API 650 or AWWA D-100.

The vent and overflow nozzles of the spent resin tank are equipped with fine mesh screens to minimize spread of particulate contamination to the radwaste tank vent system.

Piping

Piping used for hydraulic transport of slurries such as ion exchange resins, filter backwash (sludge), and waste tank sludge are specifically designed to assure trouble-free operation. Pipe flow velocities are sufficient to maintain a flow regime appropriate to the slurry being transported (ion exchange resins, filter backwash, or tank sludge). An adequate water/solids ratio is maintained throughout the transfer. Slurry piping is provided with automatic flushing with a sufficient water volume to flush the pipe clean after each use, e.g., at least two pipe volumes.

11.4.3 Safety Evaluation

The SWMS has no safety-related function. There is no liquid plant discharge from the SWMS. Failure of the subsystem does not compromise any safety-related system or component nor does it prevent shutdown of the plant. No interface with the Class 1E electrical system exists.

11.4.4 Testing and Inspection Requirements

The SWMS is given a pre-operational test as discussed in Chapter 14. Thereafter, portions of the subsystems are tested as needed.

During initial testing of the system, the pumps and the other equipment will be performance tested to demonstrate conformance with design flows and process capabilities. An integrity test is performed on the system upon completion.

Provisions are made for periodic inspection of major components to ensure capability and integrity of the subsystems.

11.4.5 Instrumentation Requirements

The SWMS is operated and monitored from the radwaste control room or local operating stations within the facility. Major system parameters, i.e., tank levels, process flow rates, etc., are indicated (recorded and alarmed as required) to provide operational information and performance assessment. Key system alarms are repeated in the main control room.

11.4.6 COL Information

None.

11.4.7 References

None.

Table 11.4-1

SWMS Component Capacities

Equipment Description	Type	Quantity	Nominal Capacity* Liter (Gal)
Tanks			
High Activity Resin Holdup Tank	Vertical, Cylindrical	1	70,000 (18,494)
Low Activity Resin Holdup Tank	Vertical, Cylindrical	1	70,000 (18,494)
Condensate Resin Holdup Tank	Vertical, Cylindrical	1	70,000 (18,494)
Low Activity Phase Separator	Vertical, Cylindrical	2	55,000 (14,531)
Concentrated Waste Tank	Vertical, Cylindrical	1	60,000 (15,852)
Pumps			
High Activity Decant Pump	Horizontal, Centrifugal	2	333L/min (88gpm)
Low Activity Decant Pump	Horizontal, Centrifugal	2	333L/min (88gpm)
High Activity Resin Circulation Pump	Horizontal, Centrifugal	2	3,330L/min (881gpm)
Low Activity Resin Circulation Pump	Horizontal, Centrifugal	1	3,330L/min (881gpm)
Condensate Resin Circulation Pump	Horizontal, Centrifugal	1	3,330L/min (881gpm)
High Activity Resin Transfer Pump	Horizontal, Centrifugal	2	379L/min (100gpm)
Low Activity Resin Transfer Pump	Horizontal, Centrifugal	1	379L/min (100gpm)
Condensate Resin Transfer Pump	Horizontal, Centrifugal	1	379L/min (100gpm)
Concentrated Waste Pump	Horizontal, Centrifugal	2	1,333L/min (352gpm)
Mobile Process Equipment			
Dewatering Equipment Fill Head	N/A	3	-
HIC Return Pump	Diaphragm	3	379L/min (100gpm)
Dryer (optional)	Drum Dryer	1	
Sorting Table	N/A	1	N/A

`

* For tanks, nominal capacity refers to the total tank capacity. Nominal capacity for pumps is in liters/min (gallons/min)

Table 11.4-2

Annual Shipped Waste Volumes

Waste Type	Estimated Annual Waste Generation m^3/yr (ft^3/yr)	Estimated Shipped Volume* m^3/yr (ft^3/yr)
Dry Active Solids (DAW):		
Combustible waste:	225 (7,951)	225 (7,951)
Compactable waste:	38 (1,343)	38 (1,343)
Other waste:	100 (3,534)	100 (3,534)
DAW Total	363 (12,827)	363 (12,827)
Wet Solid Wastes:		
RWCU Spent Bead Resin:	7.6 (269)	7.6 (269)
FAPCS Spent Bead Resin:	8.0 (283)	8.0 (283)
Condensate Purification System Spent Bead Resin:	33.8 (1,194)	33.8 (1,194)
LWMS Spent Bead Resin:	5.4 (191)	5.4 (191)
Condensate Purification System Filter Sludge:	5.2 (184)	5.2 (184)
LWMS Filter Sludge:	0.8 (28.3)	0.8 (28.3)
LWMS Concentrated Waste:	50 (1,767)	25 (883)
Wet Solid Waste Total	111 (3,922)	85.8 (3,032)

* Note the goal value is a long term average of resins and sludges in the dewatered condition and all other wastes packaged for shipment. The values for resins and sludges in the above table are volumes packaged for shipment.

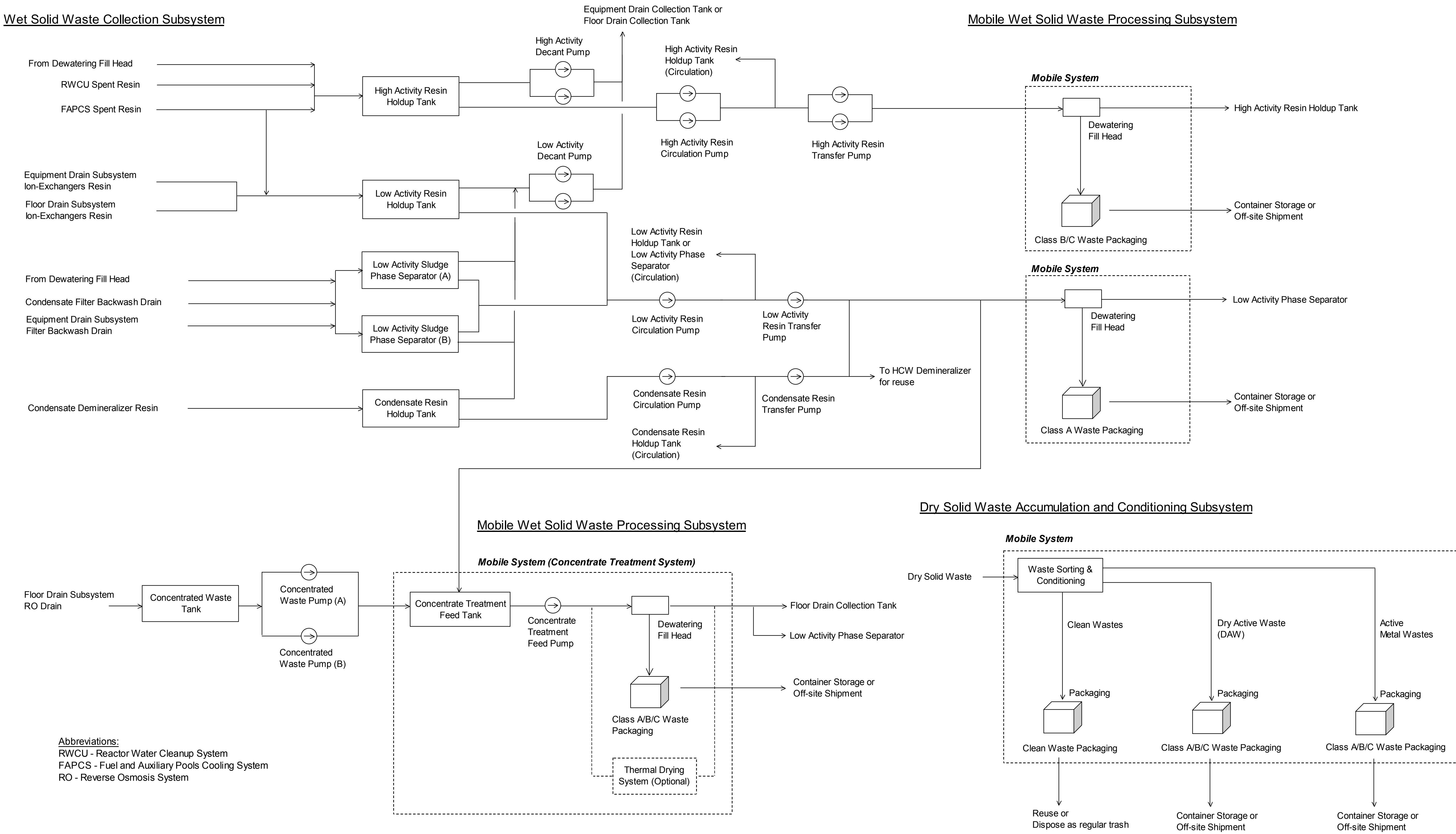


Figure 11.4-1. Solid Waste Management System Process Diagram

11.5 PROCESS RADIATION MONITORING SYSTEM

The Process Radiation Monitoring System (PRMS) is provided to allow determination of the content of radioactive material in various gaseous and liquid process and effluent streams. The design objective and criteria are based on the following requirements:

- Radiation instrumentation required for safety and protection.
- Radiation instrumentation required for monitoring and plant operation.

All radioactive release points/paths within the plant are identified and monitored by this system. All other release points/paths of the plant are located in clean areas where radiological monitoring is not required.

This system provides continuous monitoring and display of the radiation measurements during normal, abnormal, and accident conditions.

11.5.1 Design Bases

11.5.1.1 Design Objectives

11.5.1.1.1 Radiation Monitors Required for Safety and Protection

The main purpose of these radiation monitoring subsystems is to initiate appropriate protective action to limit the potential release of radioactive materials to the environment if predetermined radiation levels are exceeded in major process/effluent streams. Another objective is to provide plant personnel with indication and alarm of the radiation levels in the major process/effluent streams.

The following PRMS subsystems provide signals that initiate automatic safety functions:

- Reactor Building Heating, Ventilating, and Air Conditioning (HVAC) exhaust air Radiation Monitoring Subsystem (RMS)
- Refuel Handling Area air exhaust RMS
- Control Room air intake supply RMS
- Drywell sumps Low Conductivity Waste/High Conductivity Waste (LCW/HCW) Discharge RMS
- Isolation Condenser Vent Discharge RMS
- Fuel Building Main Area HVAC RMS

11.5.1.1.2 Radiation Monitors Required for Plant Operation

The main purpose of these radiation monitoring subsystems is to provide plant personnel with measurements of the content of radioactive material in important gaseous and liquid effluent and process streams. Additional objectives are to initiate discharge valve isolation on the offgas or liquid radwaste systems if predetermined release rates are exceeded, and to provide for sampling at certain radiation monitor locations to allow determination of specific radionuclide content.

The following PRMS subsystems are provided to meet the above design objectives:

- Monitoring Gaseous Effluent Streams
  - Stack RMS
  - Turbine Building HVAC RMS
  - Turbine Compartment Area Exhaust RMS
  - Radwaste Building Ventilation Exhaust RMS
  - Main Turbine Gland Seal Condenser Exhaust RMS
  - Fuel Building Ventilation Exhaust RMS
  - Turbine Building Ventilation Vent RMS
  - Containment Overpressure Protection System Discharge RMS
  - Fuel Building Ventilation Exhaust Filter Air Handling Unit (AHU) RMS
- Monitoring Liquid Effluent Streams
  - Liquid Radwaste Discharge RMS
- Monitoring Gaseous Process Streams
  - Main Steam Line RMS
  - Offgas Pre-treatment sampling RMS
  - Offgas Post-treatment sampling RMS
  - Charcoal vault ventilation exhaust RMS
  - Drywell Fission Product RMS
- Monitoring Liquid Process Streams
  - Reactor Component Cooling Water Intersystem Leakage RMS
- Monitoring Gaseous Intake Streams
  - Technical Support Center Ventilation RMS

11.5.2 System Design Bases and Criteria

The instrumentation used in the subsystems of the PRMS is in conformance with the relevant requirements of:

- General Design Criteria (GDC) 19, 60, and 64 of 10 CFR 50 Appendix A
- Standard Review Plan 11.5 of NUREG-0800.
- Applicable provisions of 10 CFR 20.1302, Regulatory Guide (RG) 1.21 and RG 1.97, and NUREG-0737, Item II.F.1, Attachments 1 and 2.

The system design provides radiation monitoring during normal reactor operations, anticipated operational occurrences, and post-accident conditions.

The safety-related process radiation monitoring subsystems are classified Safety Class 2, Seismic Category I. These subsystems conform to the quality assurance requirements of 10 CFR 50 Appendix B.

11.5.2.1 Radiation Monitors Required for Safety

The design criteria for the safety-related functions as defined in Subsection 11.5.1.1 include the following functional requirements:

- Withstand the effect of natural phenomena (e.g., earthquakes) without loss of capability to perform their functions;
- Perform the intended safety functions in the environment resulting from normal and abnormal conditions (e.g., loss of HVAC and isolation events);
- Meet the reliability, testability, independence, and failure mode requirements of engineered safety features;
- Provide continuous output of radiation levels to the main control room;
- Permit checking of the operational availability of each channel during reactor operation with provisions for calibration function and instrument checks;
- Ensure an extremely high probability of accomplishing safety functions in the event of anticipated operational occurrences;
- Initiate protective action when operational limits are exceeded;
- Annunciate the high radiation levels in the main control room to alert operating personnel of abnormal conditions;
- Insofar as practical, provide self-monitoring of the radiation monitors to the extent that power failure or equipment failure causes annunciation in the main control room and initiation of the required protective action;
- Register full-scale output if radiation detection exceeds full scale;
- Use instrumentation compatible with anticipated radiation levels and ranges expected under normal, abnormal and accident conditions, per Regulatory Guide (RG) 1.97;
- Use redundant divisional channels that satisfy the separation and single failure criteria, for the initiation of safety functions.

11.5.2.2 Radiation Monitors Required for Plant Operation

The design criteria for operational radiation monitoring shall include the following functional requirements:

- Provide continuous indication of radiation levels in the main control room;
- Annunciate the high radiation levels in the main control room to alert operating personnel to the abnormal conditions;

- Insofar as practical, provide self-diagnosis of the radiation monitors to the extent that power failure or equipment failure causes annunciation in the main control room and isolation of the effluents paths as required;
- Monitor a representative sample of the bulk stream or volume;
- Incorporate provisions for calibration and functional checks;
- Use instrumentation compatible with anticipated radiation levels and ranges expected under normal, abnormal and accident conditions (Regulatory Guide 1.97);
- Register full-scale output if radiation detection exceeds full scale.

11.5.3 Subsystem Description

11.5.3.1 Radiation Monitors Required for Safety

The design description of each radiological monitoring and sampling function as identified in Subsection 11.5.1 is provided in this section under its designated name. The types of instrumentation, together with pertinent parameters for each subsystem, are presented in Tables 11.5-1 and 11.5-2.

11.5.3.1.1 Reactor Building HVAC Exhaust Radiation Monitoring Subsystem (RMS)

This subsystem monitors the gross radiation level in the exhaust duct of the Reactor Building ventilation system from the Reactor Building Exhaust duct and the Refueling Area Air Exhaust duct. A high activity level in the ductwork could be due to fission gases from a leak or an accident.

The subsystem consists of four redundant instrument channels. Each channel consists of a gamma-sensitive detector and a Main Control Room (MCR) radiation monitor.

The detectors are located adjacent to the exhaust ducting upstream of the ventilating system isolation valves and monitor the RB HVAC vent exhausts. The detectors are physically located upstream of the ventilation exhaust duct isolation dampers such that closure of the dampers can be accomplished prior to exceeding radioactive effluent Technical Specification limits.

Any two-out-of-four channel trips result in the closure of the Reactor Building ventilating exhaust ventilation dampers and stoppage of the RB HVAC exhaust fans.

Trip circuits initiate their respective alarms in the MCR.

The range of channel measurement and display is as shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide sufficient coverage for radioactivity released during normal operation up to the amount associated with a refueling accident and the subsequent ventilation flow into the Reactor Building Ventilation.

11.5.3.1.2 Refuel Handling Area Ventilation Exhaust RMS

This subsystem monitors the gross radiation level in the refuel handling area ventilation exhaust duct. The system consists of four channels that are physically and electrically independent of each other. Each channel consists of a gamma-sensitive detector and a MCR radiation monitor.

This subsystem performs the same trip functions as those described in Subsection 11.5.3.1.1 for the Reactor Building HVAC exhaust radiation monitoring.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide sufficient coverage for radioactivity released during normal operation up to the amount associated with a refueling accident and the subsequent flow into the Reactor Building Ventilation.

11.5.3.1.3 Control Building HVAC RMS

The Control Building HVAC radiation monitoring subsystem is provided to detect the gross radiation level in the normal outdoor air supply and automatically initiates closure of the outdoor air intake and the exhaust dampers, and startup of the emergency air filtration system. The emergency air filtration system fans are started and area exhaust fans stopped on high radiation.

The Control Building HVAC consists of two redundant but independent subsystems.

The radiation monitors for each of the Control Building HVAC subsystems consist of four redundant channels to monitor the air intake to the building.

The monitors meet the requirements for Class 1E components to provide appropriate reliability. The system warns of the presence of significant air contamination in inlet air and provides isolation of the Control Building intake air ducts.

Each radiation channel consists of a gamma sensitive detector and a radiation monitor that is located in the MCR.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to cover normal operation and be sensitive enough to initiate isolation of the MCR prior to exceeding 0.05 Sieverts whole body or its equivalent to any part of the body.

11.5.3.1.4 Drywell Sumps LCW/HCW Discharge RMS

This subsystem monitors the gross radiation level in the liquid waste transferred in the drain line from the drywell low conductivity waste (LCW) and high conductivity waste (HCW) sumps to the Radwaste System. One monitoring channel is provided in each sump drain line. Each channel uses a gamma sensitive radiation detector that is located near the drain line from the sump just downstream from the outboard isolation valve. The output from each detector is fed to radiation monitors in the MCR for display and annunciation.

Automatic isolation of the two sump discharge pipes occurs if high radiation levels are detected during liquid waste transfers.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide sufficient coverage for expected radioactivity concentrations due to accident source terms in these sumps and address the TMI concern about unmonitored transfer of wastes from the containment to the radwaste facility.

11.5.3.1.5 Isolation Condenser Vent Exhaust RMS

This subsystem monitors the gross radiation from the atmospheric pool area above each isolation condenser. The subsystem consists of sixteen channels (four per isolation condenser vent) that are physically and electrically independent of each other. Each channel consists of a gamma-sensitive detector and a MCR radiation monitor.

This subsystem initiates isolation of the affected isolation condenser by closure of isolation valves in the steam line to the condenser and in the condensate return line from the condenser.

The detectors monitor radioactivity in the isolation condenser discharge vent that might have resulted from a tubing break or a defective condenser.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide sufficient coverage for radioactivity released prior to exceeding Technical Specification limits.

11.5.3.1.6 Fuel Building Main Area HVAC RMS

This subsystem monitors the gross radiation level in the Fuel Building Area HVAC exhaust duct. The system consists of four channels that are physically and electrically independent of each other. Each channel consists of a gamma-sensitive detector and a MCR radiation monitor. The subsystem monitors the radiation level of the air exiting the spent fuel pool and the associated fuel handling areas as well as the rooms with the fuel pool cooling and cleanup equipment.

This subsystem provides inputs to logic that results in the energization of the Fuel Building Area HVAC and a trip of the Fuel Building Main Area HVAC.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide sufficient coverage for radioactivity released during normal operation up to the amount associated with a refueling accident and the subsequent flow into the Fuel Building Ventilation.

11.5.3.2 Radiation Monitors Required for Plant Operation

See Table 11.5-3 and Figure 11.5-1 for diagrammatic information concerning the placement of the PRM subsystems.

Information on these monitors is presented in Table 11.5-2.

11.5.3.2.1 Main Steam Line (MSL) RMS

This subsystem monitors the gross gamma radiation level of the steam transported by the main steam lines in the MSL tunnel. The normal radiation level is produced primarily by coolant activation gases plus smaller quantities of fission gases being transported with the steam.

The MSL radiation monitors consist of four redundant instrument channels. Each channel consists of a local gamma detector and a radiation monitor located in the main control room.

The detectors are physically located near the main steam lines just downstream of the outboard main steam line isolation valves (MSIVs) in the steam tunnel. These detectors are arranged so that they are capable of detecting significant increases in radiation level with any number of the main steam lines in operation.

The subsystem is utilized to initiate shutdown of the main turbine condenser mechanical vacuum pump (MVP) and MVP line discharge valve closure. Channel trips are annunciated in the MCR. Although the subsystem is qualified as safety, its function is non-safety.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide detection from normal background up to, and including, gross releases of fission products into the reactor vessel and subsequent transport to the steam line.

11.5.3.2.2 Offgas Pre-Treatment RMS

This subsystem monitors radioactivity in the main turbine condenser Offgas after it has passed through the Offgas condenser and moisture separator. The monitor detects the gross radiation level that is attributable to the fission gases that are produced in the reactor and then transported with steam through the turbine to the main turbine condenser.

A continuous sample is extracted from the Offgas pipe, then passed through a sample chamber and a sample panel before being returned to the suction side of the steam jet air ejector (SJAE). The sample chamber is a stainless steel pipe that is internally polished to minimize plate-out. It can be purged with room air to check detector response to background radiation. Sample line flow is measured and indicated on the sample panel. A gamma-sensitive detector, positioned adjacent to the sample chamber, is connected to a local radiation monitor.

The radiation level reading can be directly correlated to the concentration of the noble gases by using a sampler to obtain a grab sample. The sample is then removed and the sample is analyzed with a multichannel gamma pulse height analyzer to determine the concentration of the various noble gas radionuclides. A correlation between the observed activity and the monitor reading permits calibration of the monitor.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to cover an offgas release rate of 3.7 Mega-Bequerels per second (MBq/s) up to approximately 3.7E5 MBq/s (after a 30 minute decay).

11.5.3.2.3 Offgas Post-Treatment RMS

This subsystem monitors radioactivity for halogens, particulates and noble gas releases during normal and accident conditions in the Offgas piping downstream of the Offgas System charcoal adsorbers and upstream of the Offgas System discharge valve. A continuous sample is extracted from the Offgas System piping, passed through two Offgas post-treatment samplers for monitoring and sampling, and returned to the Offgas System piping. Two local radiation monitors, connected to gamma-beta sensitive radiation detectors, analyze and visually display the measured radiation level.

The sample panel shielded chambers can be purged with room air to check detector response to background radiation. Sample line flow is measured and indicated on the sample panel.. A remotely- operated check source for each detector assembly is used to check operability of the channel.

Each radiation monitor has trip circuits that actuate corresponding main control room annunciators.

High or low flow measured at the sample panel actuates an annunciator in the MCR to indicate abnormal flow.

The trip outputs are used to initiate closure of the Offgas System discharge and bypass valves. The trip setpoint is set so that valve closure is initiated prior to exceeding offsite dose limits. A channel trip is also used to initiate alignment of the Offgas System flow valves to achieve treatment through the charcoal vault.

A vial sampler panel similar to the pre-treatment sampler panel is provided for grab sample collection to allow isotopic analysis and monitor calibration.

Tritium sampling is also provided by the subsystem.

The ranges of channel display are shown in Table 11.5-1 and Table 11.5-2 for particulates and halogens. The ranges are selected to cover an Offgas release rate of 3.7E5 Bq/s to 3.7E4 MBq/s. The lower limit is based on the approximate value of an expected release rate for Kryptons and Xenons in the Offgas System. The upper limit is set by the plant release limit, which in turn is set by such factors as site size, meteorology, release level, and prevailing regulatory positions.

11.5.3.2.4 Charcoal Vault RMS

The charcoal vault is monitored for gross gamma radiation level with a single instrument channel. The channel includes a gamma sensitive detector and a radiation monitor. The detector is located outside the vault on the HVAC exhaust line from the vault. The radiation monitor is located locally.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. This range is selected to indicate leakage from charcoal vault into the ventilation/refrigeration duct.

11.5.3.2.5 Turbine Building Ventilation Stack RMS

This subsystem monitors the Turbine Building Ventilation Vent discharge for halogens, particulates and noble gas releases during normal and accident conditions.

A representative sample is continuously extracted through an isokinetic probe in accordance with ANSI N13.1, passed through the sample panel for monitoring and sampling, and then returned to the Turbine Building Ventilation Vent. The radiation detector assembly consists of shielded gas chambers that house gamma-beta sensitive detectors and check sources. A local radiation monitor analyzes and visually displays the measured radiation level.

The sample chamber is equipped with a check source to test detector response, thus checking operability of the radiation channel.

The radiation monitor initiates trips for alarm indications on high radiation. Also, the sampled line is monitored for high or low flow conditions.

Tritium sampling is also provided by the subsystem

The ranges of channel display are shown in Table 11.5-1 and Table 11.5-2 for particulates and halogens. These ranges are selected to cover ranges stipulated by 10 CFR 20.

11.5.3.2.6 Liquid Radwaste Discharge RMS

This subsystem continuously monitors the radioactivity in the radwaste liquid during its discharge to the environment and stops the discharge on detection of a high radiation level.

Liquid waste can be discharged from the sample tanks containing liquids that have been processed through one or more treatment systems such as evaporation, filtration, and ion exchange. During the discharge, the liquid is extracted from the radwaste liquid discharge process pipe, passed through a liquid sample panel that contains a detection assembly for gross radiation monitoring, and returned to the process pipe. The detection assembly consists of a detector mounted in a shielded sample chamber equipped with a check source. A local radiation monitor analyzes and visually displays the measured gross radiation level.

The sample panel chamber can be drained to allow assessment of background buildup. Sample line flow is measured and indicated on the sample panel. A check source can be used to check operability of the channel.

The radiation monitor has trip circuits that are used to stop the discharge to the environment.

The range of channel display is shown in Table 11.5-1 and Table 11.5-2. This lower range limit addresses 10 CFR 20, App. B, Table 2; the upper limit addresses guidance of ANSI-N42- 1980.

11.5.3.2.7 Reactor Component Cooling Water Intersystem Leakage RMS

This subsystem consists of two channels. Each channel monitors for intersystem radiation leakage into the respective RCCW system loop.

Each channel consists of a detector that is located near the RCCW heat exchanger exit pipe. Each channel provides individual channel trips on high radiation level and downscale/inoperative indication for annunciation in the MCR.

The range of channel display is shown in Table 11.5-1 and Table 11.5-2. This range addresses the lower limit of the 10 CFR 20, App. B, Table II, concentrations for Cs-137, and has additional decades to provide a sufficient margin for higher concentrations of radioactivity.

11.5.3.2.8 Radwaste Building Ventilation Exhaust RMS

This subsystem monitors the Radwaste Building ventilation discharge to the Radwaste Building vent for halogens, particulates and noble gas during normal and accident conditions. Each instrument channel consists of a local detector and a radiation monitor.

The radiation monitor provides upscale and inoperative trips.

Tritium sampling is also provided by the subsystem.

A remotely-operated gamma check source is provided for testing channel operability.

The trip signals are annunciated in the Radwaste Building control room and in the MCR. The ranges of channel display are shown in Table 11.5-1 and Table 11.5-2 for particulates and halogens. The ranges are selected to cover the values stipulated by 10 CFR 20 and ANSI N42.18.

11.5.3.2.9 Turbine Building Ventilation Exhaust RMS

This subsystem monitors the vent exhaust in the Turbine Building for gross radiation levels. The monitoring is provided by four channels (two redundant sets). Two redundant channels monitor radiation in the compartment area air exhaust duct and the other two redundant channels monitor the radiation in the ventilation system air exhaust from the clean area. Each channel uses a gamma sensitive detector located adjacent to the monitored exhaust duct. The outputs from the detectors are fed into radiation monitors for display and annunciation. Each monitor provides alarm trips on radiation high and on inoperative in the MCR.

The range of channel display is shown in Table 11.5-1 and Table 11.5-2. The indicated range is selected to cover the dynamic range of expected concentrations.

11.5.3.2.10 Main Turbine Gland Seal Steam Condenser Exhaust RMS

This subsystem monitors the releases to the Turbine Building Ventilation Vent from the turbine gland seal system. The releases are continuously sampled and monitored for noble gases. The output signal is displayed in the MCR. The channel has an upscale alarm and an inoperative alarm.

A grab sample of the flow path can be extracted for laboratory analysis. Samples of halogens and particulates can be collected on filters for periodic analysis.

A locally operated gamma check source is provided for testing channel operability.

The range of channel display is shown in Table 11.5-1 and Table 11.5-2. The indicated range is selected to cover the range of expected concentrations from the gland seal condenser exhaust.

11.5.3.2.11 Drywell Fission Product RMS

This subsystem, consisting of two channels, continuously monitors noble gases and particulates in the drywell air space under normal operating conditions. These measurements are used to demonstrate compliance with RG 1.45 for leak detection.

Each radiation monitor provides upscale and inoperative alarms that are indicated in the MCR.

The range for the particulate of channel display is given in Table 11.5-1 and Table 11.5-2. This lower limit of detectability is sufficient to indicate the equivalent of 3.785 liters per minute (lpm) leak rate (normal reactor water) within 60 minutes.

The range for the gaseous of channel display is given in Table 11.5-1 and Table 11.5-2. This lower limit of detectability is sufficient to indicate the equivalent of 3.785 lpm leak rate (normal reactor water) within 60 minutes.

11.5.3.2.12 Technical Support Center (TSC) Ventilation RMS

This subsystem continuously monitors the intake ventilation duct of the Technical Support Center with a single gamma sensitive radiation monitor. Upon detection of radioactivity at the outside air intake, the Air Handling Unit (AHU) outdoor air damper for the TSC is closed and the filter train fan is started.

This monitor provides upscale and inoperative alarms that are alarmed in the MCR.

The range of channel measurement and display is given in Table 11.5-1 and Table 11.5-2. This range is selected to cover normally expected concentrations of radioactivity in air, up to and including, limiting concentrations indicated in 10 CFR 20.

11.5.4 Regulatory Evaluation

The system design for radiation monitoring is in conformance with the relevant requirements and criteria that are stipulated in the codes and standards that are identified in Subsection 11.5.2. Radiation monitoring is provided during reactor operation and under post-accident conditions. Specifically, the following requirements are evaluated for compliance:

11.5.4.1 Basis for Monitor Location Selection

The detector locations are selected, per RG 1.21 and Standard Review Plan 11.5, to monitor all the major and potentially significant paths for release of radioactive material during normal reactor operation including anticipated operational occurrences. The radioactivity levels in liquid and gaseous effluent releases are monitored, measured, displayed and recorded.

11.5.4.2 Expected Radiation Levels

Expected radiation levels are within the ranges specified in Tables 11.5-1 and 11.5-2.

11.5.4.3 Instrumentation

Grab samples are analyzed to identify and quantify the specific radionuclides in effluents. The results from the sample analysis are used to establish relationships between the gross gamma monitor readings and concentrations or release rates of radionuclides in continuous effluent releases. Tables 11.5-4 through 11.5-7 provide summary information concerning the frequency, analysis, sensitivity and purpose for both liquid and gaseous process and effluent extracted samples that are analyzed in the health physics laboratory.

11.5.4.4 Setpoints

The trip setpoints for the safety-related radiation monitors are specified in the plant Technical Specifications. Trip setpoints for nonsafety-related radiation monitors are specified in the plant Operating Procedures.

11.5.5 Process Monitoring and Sampling

11.5.5.1 Implementation of General Design Criterion 19

The Main Control Building is provided with detectors that sense radiation in the intake air supply to the control building and provide warning and initiate actions to protect operating personnel for access and occupancy of the control room under accident conditions.

In addition, the Technical Support Center ventilation air intake is provided with radiation detection to initiate actions to protect personnel.

11.5.5.2 Implementation of General Design Criterion 60

All potentially significant radioactive discharge paths are equipped with a control system to automatically isolate the discharge on indication of a high radiation level. These include:

- Offgas Post-Treatment
- Reactor Building HVAC Air Exhaust
- Fuel Handling Area Ventilation Exhaust
- Drywell Sump LCW/HCW discharge
- Radwaste Liquid Discharge

11.5.5.3 Implementation of General Design Criterion 63

Radioactive waste systems and their associated handling areas are monitored for excessive radiation levels. These include:

- Offgas Pre-Treatment and Post-Treatment
- Radwaste Building Ventilation Exhaust
- Fuel Building Ventilation Exhaust

11.5.5.4 Implementation of General Design Criterion 64

Radiation levels in the reactor containment atmosphere, effluent discharge paths and important process streams are monitored for radioactivity. These paths and areas include:

- Main steam line
- Offgas pre-treatment and post-treatment
- Carbon vault ventilation
- Intersystem leakage into Reactor Component Cooling Water
- Turbine Building Ventilation Vent
- Radwaste Building Ventilation Exhaust
- Turbine Building Exhaust (Normal Ventilation & Area Exhaust)
- Turbine Gland Seal Steam Condenser Exhaust
- Containment Overpressure Protection System
- Drywell Fission Products

11.5.5.5 Basis for Monitor Location Selection

The detector locations are selected to monitor the major and potentially significant paths for release of radioactive material during normal reactor operation including anticipated operational occurrences, thus meeting the intent of RG 1.21 and SRP 11.5. Monitoring of each major path provides measurements that are representative of releases to demonstrate compliance with 10 CFR 20 limits.

11.5.5.6 Expected Radiation Levels

Expected radiation levels are listed in Tables 11.5-1 and 11.5-2.

11.5.5.7 Instrumentation

Grab samples are analyzed to identify and quantify the specific radionuclides in process streams. The results from the sample analysis are used to establish relationships between the gross gamma monitor readings and concentration and radionuclides in the process streams.

11.5.5.8 Setpoints

The trip setpoints for the safety-related radiation monitors are specified in the plant Technical Specifications. Trip setpoints for non-safety-related radiation monitors are specified in the plant operating procedures.

11.5.6 Calibration and Maintenance

11.5.6.1 Inspection and Tests

During reactor operation, daily checks of system operability are made by observing channel behavior. At periodic intervals during reactor operation, the detector response of each monitor provided with a remotely positioned check source is verified, together with the instrument background count rate, to ensure proper functioning of the monitors. Any detector whose response cannot be verified by observation during normal operation or by using the remotely positioned check source is response checked with a portable radiation source. A record is maintained showing the background radiation level and the detector response.

The system incorporates self-diagnostics and online calibration for its process radiation monitors that operate continuously to assure maximum availability and minimum down time. Also, each radiation channel is tested and calibrated periodically using a standard radiation source to validate channel operability.

The following monitors have alarm trip circuits that can be tested by using test signals or portable gamma sources:

- Main Steam line
- Reactor Building Vent exhaust
- Refuel Handling Area Vent exhaust
- Control building HVAC air intake supply
- Fuel Building Main Area HVAC
- Isolation Condenser Vent Exhaust
- Turbine Building Ventilation Vent Exhaust
- Turbine Building Vent exhaust (normal & compartment areas)
- Charcoal Vault Vent Exhaust
- Containment Overpressure Protection System
- Drywell HCW/LCW Sumps Discharge
- Technical Support Center Control Ventilation Intake
- Offgas Pre-Treatment

The following monitors include built-in check sources:

- Offgas Post-Treatment
- Liquid Radwaste Discharge

- Radwaste Building Vent Exhaust
- Main Turbine Gland Seal Steam Condenser Exhaust
- Turbine Building Ventilation Vent
- Drywell Fission Product
- Reactor Component Cooling Water Intersystem leakage
- Fuel Building Ventilation Stack

11.5.6.2 Calibration

Calibration of radiation monitors is performed using certified commercial radionuclide sources traceable to the National Institute of Standards and Technology. Each continuous monitor is calibrated during plant operation or during the refueling outage if the detector is not readily accessible. Calibration can also be performed on the applicable instrument by using liquid or gaseous radionuclide standards or by analyzing particulate iodine or gaseous grab samples with laboratory instruments.

11.5.6.3 Maintenance

Control and routine maintenance and cleaning operations of the sampling systems is conducted from either the front or the top of the skid or panel. Lifting eyes or other devices are provided for hoisting the units, to facilitate replacement if it is ever required.

Instrument modules are design to facilitate calibration checks and troubleshooting. Accessibility for power supply adjustments is provided.

Ssampling racks and electronic modules are serviced and maintained on an annual basis or in accordance with the operational instructions to ensure reliable operation. Such maintenance includes servicing and replacement of defective components and adjustments, as required, after performing a test or calibration check. If any work is performed that would affect the calibration of the instrument, a re-calibration is performed following the maintenance operation.

11.5.7 COL Information

None

11.5.8 References

None

Table 11.5-1

Process and Effluent Radiation Monitoring Systems

Monitored Process	No. of Channels	Sample Line or Detector Location	Displayed Channel Range
A. Safety-Related Monitors			
Main Steam Line Tunnel Area	4	Immediately downstream of plant main steam line isolation valve	1E-2 to 1E4 mSv/h
Reactor Building Ventilation Exhaust	4	Exhaust duct upstream of exhaust ventilation isolation valve	1E-4 to 1E0 mSv/h
Refuel Handling Area Air Ventilation Exhaust	4	Exhaust duct upstream of exhaust ventilation isolation valve	1E-4 to 1E0 mSv/h
Control Building Air Intake	8	Intake duct upstream of intake ventilation isolation valve	1E-4 to 1E0 mSv/h
Drywell Sumps LCW/HCW Discharge	2	Drain line from LCW & HCW sumps	1E-2 to 1E4 mSv/h
Fuel Building Main Area HVAC	4	Exhaust duct upstream of exhaust ventilation isolation valve	1E-4 to 1E0 mSv/h
Isolation Condenser Vent Discharge	16	Exhaust of isolation condensers	1E-4 to 1E0 mSv/h
B. Monitors Required for Plant Operation			
Stack	3	On Stack exhaust	1E -3 to 1E 10 MBq/m^3 (gaseous) 1E -6 to 1E 7 MBq/m^3 (particulate & halogen)
Turbine Building Vent exhaust (Normal Ventilation & Area Exhausts)	4	Exhaust duct	1E-4 to 1E0 mSv/h
Turbine Building HVAC Vent	3	On Turbine Building exhaust line	1E-4 to 1E0 mSv/h

Table 11.5-1

Process and Effluent Radiation Monitoring Systems

Monitored Process	No. of Channels	Sample Line or Detector Location	Displayed Channel Range
Radwaste Building Ventilation Exhaust	3	On Radwaste Building exhaust line	1E-3 to 1E3 MBq/m^3 (gaseous) 1E-7 to 1E-1 MBq/m^3 (particulate) 1E-7 to 1E-1 MBq/m^3 (iodine)
Main Turbine Gland Seal Steam Condenser Exhaust	1	Sample line	1E-3 to 1E3 MBq/m^3
Liquid Radwaste Discharge	1	Sample line	1E-3 to 1E3 MBq/m^3
Offgas Pre-Treatment	1	Sample line	1E-2 to 1E4 mSv/h
Offgas Post-Treatment Skid A	2	Sample line	1E0 to 1E7 MBq/m^3 (gaseous) 1E-7 to 1E1 MBq/m^3 (particulate) 1E-7 to 1E1 MBq/m^3 (iodine)
Offgas Post Treatment Skid B		Sample Line	1E0 to 1E7 MBq/m^3 (gaseous)
Charcoal Vault Ventilation Exhaust	1	On charcoal vault HVAC exhaust line	1E-2 to 1E4 mSv/h
Reactor Component Cooling Water Intersystem Leakage	3	Each RCCW heat exchanger line exit	1E-1 to 1E5 MBq/m^3
Technical Support Center Ventilation	1	Exhaust duct	1E4 to 1E0 mSv/h
Drywell Fission Product (Particulate)	1	Sample line	1E-7 to 1E-1 MBq/m^3
Drywell Fission Product (Gaseous)	1	Sample line	1E-1 to 1E4 MBq/m^3

Table 11.5-1

Process and Effluent Radiation Monitoring Systems

Monitored Process	No. of Channels	Sample Line or Detector Location	Displayed Channel Range
Turbine Building Ventilation Stack	3	Sample line	1E-3 to 1E3 MBq/m^3 (gaseous) 1E-7 to 1E-1 MBq/m^3 (particulate) 1E-7 to 1E-1 MBq/m^3 (iodine)
Fuel Building Ventilation Exhaust Filter AHU		On AHU's	1E-4 to 1E0 mSv/h
Fuel Building Ventilation Stack		Sample Line	1E-3 to 1E3 MBq/m^3 (gaseous) 1E-7 to 1E-1 MBq/m^3 (particulate) 1E-7 to 1E-1 MBq/m^3 (iodine)
MBq/m^3 = mega-becquerel per cubic meter; Gy/h = Gray per hour; Sv/h = Sieverts per hour; mSv/h = milli-Sieverts per hour			

Table 11.5-2

Process Radiation Monitoring System (Gaseous and Airborne Monitors)

Radiation Monitor	Configuration	Dynamic Detection Range *	Principal Radionuclides Measured	Expected Activity **	Alarms and Trips
A. Safety-Related Monitors					
Main Steam Line	Offline (adjacent to Steam Lines)	≈ 1.4E 2 to 1.4 E 8 MBq/m3	N-16, O-19 & Coolant activation gases	6.4E4 MBq/m3 (N-16)	DNSC INOP High High-High
Reactor Building HVAC Exhaust	Inline (adjacent to vent duct)	≈ 1.5E 3 to 1.5E 7 MBq/m3	Xe-133	2.5E-3 MBq/m3	DNSC/INOP High High-High
Refuel Handling Area Air Exhaust	Inline (adjacent to vent duct)	≈ 7.3E2 to 7.3E6 Bq/m3	Xe-133	2.8E-4 MBq/m3	DNSC/INOP High High-High
Control Building Air Intake	Offline (adjacent to air intake duct)	≈ 8E1 to 8E 5 MBq/m3	Xe-133	Negligible	DNSC/INOP High High-High
Fuel Building Main Area HVAC	Inline (adjacent to vent duct)	≈ 7.4E 1 to 7.4E 5 MBq/m3	Xe-133	0	DNSC/INOP High High-High
Isolation Condenser Vent Discharge	Inline (adjacent to vent duct)	≈ 1.5E 3 to 1.5E 7 MBq/m3	Xe-133	0	DNSC/INOP High High-High
B. Monitors Required for Plant Operation					
Offgas Post-Treatment	Offline	≈ 8 E-3 to 8 E 3 MBq/m3 ≈2.6 E -3 to 2.6 E3 MBq/m3 ≈3.7 E -7 to 3.7E -1 Bq/m3 ≈ 7.4 E -7 to 7.4E-1	Xe-133 Kr-85 Cs-137 I-131	Negligible Negligible Negligible Negligible	Abnormal Flow DNSC/INOP High High-High High-High-High

Table 11.5-2

Process Radiation Monitoring System (Gaseous and Airborne Monitors)

Radiation Monitor	Configuration	Dynamic Detection Range *	Principal Radionuclides Measured	Expected Activity **	Alarms and Trips
Offgas Pre-Treatment	Offline (adjacent to sample chamber)	≈ 1.7 E 2 to 1.7 E 8 MBq/m^3 ≈ 1.0 E 2 to 1.0 E 8 MBq/m^3	Xe-138 Kr-88	≈ 1.8 E 5 MBq/m^3 ≈ 9.8 E 4 MBq/m^3	DNSC/INOP High High-High
Main Turbine Gland Seal Steam Condenser Exhaust	Offline	≈ 8 E -3to 8E 3 MBq/m^3 ≈ 2.6 E -3 to 2.6E 3 MBq/m^3	Xe-133 Kr-85	0 0	Abnormal Flow DNSC/INOP High High-High
Charcoal Vault Ventilation Exhaust	Inline (adjacent to vent duct)	≈ 5.1E 2 to 5.1E 8 MBq/m^3 ≈1 E 2 to 1 E 8 MBq/m^3	Xe-133 Kr-85	0 0	DNSC/INOP High
Turbine Building HVAC Exhaust (Normal)	Inline (adjacent to vent duct)	≈ 1.7 to 1.7E4 MBq/m^3 ≈ 3E1 to 3E5 MBq/m^3	Xe-133 Kr-85	Negligible 0	DNSC/INOP High
Turbine Building Compartment Area Exhaust	Inline (adjacent to vent duct)	≈ 2 to 2 E 4 MBq/m^3 ≈ 5 E 1 to 5 E 5 MBq/m^3	Xe-133 Kr-85	Negligible 0	DNSC/INOP High
Turbine Building Ventilation Stack	Offline	≈ 8 E -3to 8 E 3 MBq/m^3 ≈ 2.6 E -3 to 2.6 E 3 MBq/m^3 ≈ 7.4E -7 to 7.4 E -1 MBq/m^3 ≈ 7.4E -7 to 7.4E-1 MBq/m^3	Xe-133 Kr-85 Cs-137 I-131	Negligible Negligible Negligible Negligible	Abnormal Flow DNSC/INOP High High-High
Stack	Offline	≈ 1 E –3 to 1 E 10 MBq/m3 ≈ 1 E –3 to 1 E 10 MBq/m3 ≈ 1 E –6 to 1 E 7 MBq/m3 ≈ 1 E –6 to 1 E 7 MBq/m3	Xe-133 Kr-85 Cs-137 I-131	≈ 1.5 E -6 MBq/m3 ≈ 2.1 E -7 MBq/m3 ≈ 1.4 E -11 MBq/m3 ≈ 4.1 E -10 MBq/m3	Abnormal Flow DNSC/INOP High High-High

Table 11.5-2

Process Radiation Monitoring System (Gaseous and Airborne Monitors)

Radiation Monitor	Configuration	Dynamic Detection Range *	Principal Radionuclides Measured	Expected Activity **	Alarms and Trips
Drywell Fission Product	Offline	≈ 8.1E-8 to 8.1E -2 MBq/m^3 ≈ 2.6E -7 to 2.6 E -1 MBq/m^3 (particulate)	Cs-137 Co-60	≈ 3 E-5 MBq/m^3 ≈ 1.6 E -4 MBq/m^3	Abnormal Flow DNSC/INOP High High-High
Drywell Fission Product	Offline	≈ 8.1E-3 to 8.1E3 MBq/m^3 ≈ 2.6E -3 to 2.6E3 MBq/m^3 (gaseous)	Xe-133 Kr-85	≈ 1.3 E -3 MBq/m^3 ≈ 3.9 E -6 MBq/m^3	DNSC/INOP High High-High
Radwaste Building Ventilation Exhaust	Offline	≈ 8 E -3 to 8 E 3 MBq/m^3 ≈ 2.6E -3 to 2.6 E 3 MBq/m^3 ≈ 7.4 E -7 to 7.4 E -1 MBq/m^3 ≈ 7.4 E-7 to 7.4E-1 MBq/m^3	Xe-133 Kr-85 Cs-137 I-131	Negligible Negligible Negligible Negligible	Abnormal Flow DNSC/INOP High High-High
Fuel Building Ventilation Stack	Offline	≈ 8 E -3 to 8 E 3 MBq/m^3 ≈ 2.6 E -3 to 2.6 E 3 MBq/m^3 ≈ 7.4 E -7 to 7.4 E-1 MBq/m^3 ≈7.4 E -7 to 7.4 E -1 MBq/m^3	Xe-133 Kr-85 Cs-137 I-131	Negligible Negligible Negligible Negligible	Abnormal Flow DNSC/INOP High High-High
Fuel Building Ventilation Exhaust AHU	Inline	≈ 5.5 to 5.5 E 4 MBq/m^3 ≈ 1E 2 to 1E 6 MBq/m^3	Xe-133 Kr-85	0 0	DNSC/INOP High
Technical Support Center Ventilation	Inline	≈ 8 E0 to 8E4 MBq/m^3 ≈ 1.7E2 to 1.7E 6 MBq/m^3	Xe-133 Kr-85	Negligible Negligible	DNSC/INOP High High-High

Table 11.5-2

Process Radiation Monitoring System (Gaseous and Airborne Monitors)

Radiation Monitor	Configuration	Dynamic Detection Range *	Principal Radionuclides Measured	Expected Activity **	Alarms and Trips
Bq/ m^3 = Becquerels per cubic meter, MB/m^3 = Mega Becquerels per cubic meter					

* Ranges are typical and will be adjusted on a plant specific basis.

** Expected radiation activities are estimated and will be updated on a plant specific basis.

Table 11.5-3

Key to Radiation Monitors Shown on Figure 11.5-1

ID on Figure 11.5-1	Description
1	Main Steamline
2	Reactor Building HVAC Exhaust Vent
3	Refuel Handling Area Air Exhaust
4	Control Room Air Intake
5	Turbine Building Ventilation HVAC Exhaust
6	Turbine Compartment Area Exhaust
7	Offgas Pre-Treatment
8	Charcoal Vault Ventilation Exhaust
9	Offgas Post-Treatment
10	Turbine Building Ventilation Stack
11	Liquid Radwaste Discharge
12	Drywell Sump LCW/HCW Discharge
13	Stack
14	Main Turbine Gland Seal Steam Condenser Exhaust
15	Reactor Component Cooling Water Intersystem Leakage
16	Drywell Fission Product
17	Radwaste Building Ventilation Exhaust
18	Fuel Building Ventilation Stack
19	Isolation Condenser Vent Discharge
20	Technical Support Center Ventilation
21	Fuel Building Main Area HVAC
22	Fuel Building Ventilation Exhaust AHU

Table 11.5-4

Process Radiation Monitoring System (Liquid Monitors)

Radiation Monitor	Configuration	Dynamic Detection Range *	Principal Radionuclides Measured	Expected Activity **	Alarms & Trips
Liquid Radwaste Discharge	Offline	≈ 2.1E3 to 2.1E3 MBq/m^3 ≈ 1.9E -2 to 1.9E 4 MBq/m^3	Cs-137 Co-60	≈ 1.1E-1 MBq/m3 ≈ 1.1E-1 MBq/m3	Abnormal Flow DNSC/INOP High High-High
Reactor Component Cooling Water Intersystem Leakage	Inline	≈ 4.3E -3 to 4.3E3 MBq/m^3 ≈ 3.6E -3 to 3.6E3 MBq/m^3	Cs-137 Co-60	≈ 3.7E-2 MBq/m3 ≈ 1.1E-1 MBq/m3	DNSC/INOP High
Drywell Sump LCW/HCW Discharge	Inline (adjacent to pipe)	≈ 4E4 to 4E10 MBq/m^3 ≈ 8E0 to 8E6 MBq/m^3	Cs-137 Co-60	≈ 8.9 MBq/m3 ≈ 4.8E1 MBq/m3	DNSC/INOP High High-High
MBq/m^3 = Mega Becquerels per cubic meter					

* Ranges are typical and will be adjusted on a plant specific basis.

** Expected radiation activities are estimated and will be updated on a plant specific basis.

Table 11.5-5

Radiological Analysis Summary of Liquid Process Samples

Sample Description	Grab Sample Frequency	Analysis	Sensitivity (MBq/m^3)	Purpose
1 Reactor Coolant				
Filtrate	Daily *	Gross gamma	$3.7x10^{-2}$	Evaluate reactor water activity
Crud	Daily	Gross gamma	$3.7x10^{-2}$	Evaluate crud activity
Filtrate	Weekly **	I-131, I-133	$3.7x10^{-3}$	Evaluate fuel cladding integrity
Crud and filtrate	Weekly	Gamma spectrum	1.85x10–3	Determine radionuclides present in system
2. Reactor Water Cleanup / Shutdown Cooling System	Biweekly	Gross gamma	$3.7x10^{-2}$	Evaluate cleanup efficiency
3. Condenser Demineralizer				
Influent	Monthly	Gross gamma	$3.7x10^{-2}$	Evaluate leakage
Effluent	Monthly	Gross gamma	$3.7x10^{-2}$	Evaluate demineralizer performance
4. Condensate storage tank	Weekly	Gross β-γ	$3.7x10^{-2}$	Evaluate water radioactivity
5. Fuel Pool Filter - Demineralizer				
Inlet & Outlet	Periodically	Gross β-γ	$3.7x10^{-2}$	Evaluate system performance
6. LCW Collector and Sampling tanks (4)	Periodically	Gross β-γ	$3.7x10^{-2}$	Evaluate system performance
7. HCW Collector Tanks (2)	Periodically	Gross β–γ	$3.7x10^{-2}$	Evaluate system performance

Table 11.5-5

Radiological Analysis Summary of Liquid Process Samples

Sample Description	Grab Sample Frequency	Analysis	Sensitivity (MBq/m^3)	Purpose
8. Solid Waste Supply Tank (evaporator bottoms)	Periodically	Gross β–γ	$3.7x10^{-2}$	Compare activity with that determined by drum readings
9. Reactor Component Cooling Water System	Weekly	Gross β–γ	$3.7x10^{-2}$	Evaluate intersystem leakage

* Daily means five times per week.

** Performed more frequently if increase noted on daily gamma count.

Table 11.5-6

Radiological Analysis Summary of Gaseous Process Samples

Sample Description	Sample Frequency	Analysis	Sensitivity (MBq/m^3)	Purpose
1. Containment Atmosphere (drywell)	Periodically and prior to entry	Gross α-β Tritium	$3.7x10^{-7}$ $3.7x10^{-2}$	Determine need for respiratory equipment
2. Offgas Pre-Treatment Sample	Monthly	Gamma spectrum	$3.7x10^{-6}$	Determine offgas activity
3. Offgas Post-Treatment Sample	Weekly	Gross β *	$3.7x10^{-7}$	Determine Offgas System cleanup
		I-131 **	$3.7x10^{-6}$	
		Gamma spectrum Tritium	$3.7x10^{-6}$ $3.7x10^{-2}$	

* On particulate filter

** On charcoal cartridge

Table 11.5-7

Radiological Analysis Summary of Liquid Effluent Samples

Sample Description	Sample Frequency	Analysis	Sensitivity (MBq/m^3)	Purpose
1. Detergent Drain Tanks	Batch *	Gross Gamma	$3.7x10^{-3}$	Effluent discharge record
2. Liquid Radwaste Effluent	Weekly **	Ba/La-140 and I-131	$1.85x10^{-3}$	Effluent discharge record
Composite of all discharges	Monthly	Gamma Spectrum	$18.5x10^{-3}$	
		Tritium	$3.7x10^{-1}$	
		Gross alpha	$3.7x10^{-3}$	
		Dissolved gas ***	$3.7x10^{-1}$	
	Quarterly	Sr-89 and Sr-90	$1.85x10^{-3}$	

* If tank is to be discharged, analysis will be performed on each batch. If tank is not to be discharged, analysis will be performed periodically to evaluate equipment performance.

** Typical batch of average release. All other samples are proportional composites.

*** If no discharge event occurs during the week, frequency shall be so adjusted.

Table 11.5-8
Radiological Analysis Summary of Gaseous Effluent Samples

Sample Description	Sample Frequency	Analysis	Sensitivity (MBq/m^3)	Purpose
1. Turbine Building Ventilation Stack *	Weekly	Gross β **	$3.7x10^{-7}$	Effluent record
		I-131 ***	$3.7x10^{-6}$	
		Ba/La-140	$3.7x10^{-5}$	
	Monthly	Gamma spectrum	$3.7x10^{-6}$	
		I-133 and I-135	$3.7x10^{-6}$	
		Tritium	$3.7x10^{-2}$	
		Gross alpha	$3.7x10^{-7}$	
	Quarterly	Sr-89 and Sr-90	$3.7x10^{-7}$	
2. Offgas Exhaust Discharge	As above	As above	As above	Effluent record
3. Gland Seal Steam Condenser Exhaust Discharge	As above	As above	As above	Effluent record
4. Radwaste Building Discharge	As above	As above	As above	Effluent record

* This includes discharges from the Reactor Building, Turbine Building, and Control Building.

** On particulate filter.

*** On charcoal cartridge.

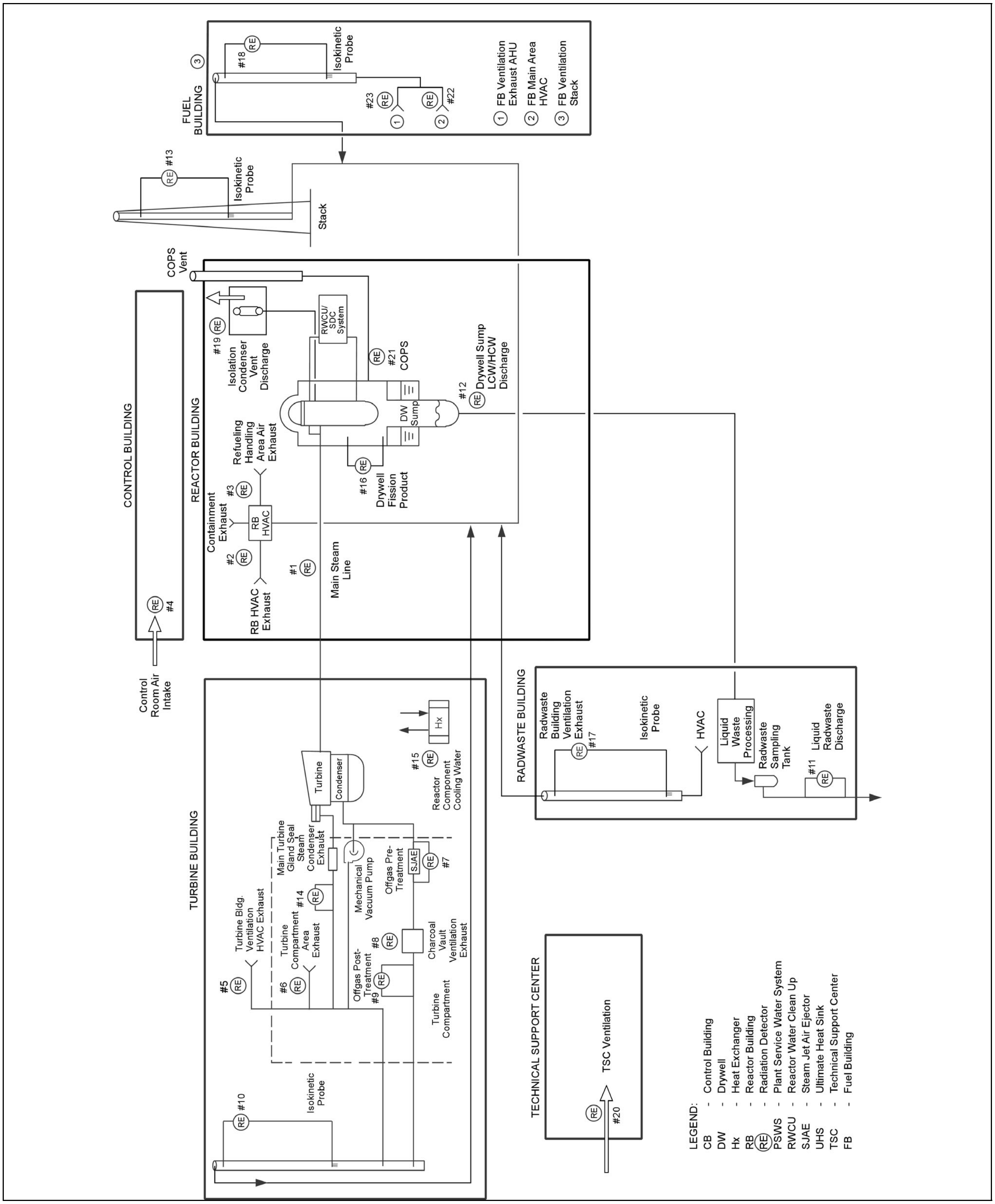


Figure 11.5-1. Location of Radiation Monitors